JC14 Rec'd PCT/PTO 19 SEP 2001

FORM PTO-1390 (Modified) (REV 11-99) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
112740-283

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/937027

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/EP00/02440	20 March 2000	19 March 1999

TITLE OF INVENTION
METHOD AND APPARATUS FOR DATA RATE MATCHING

APPLICANT(S) FOR DO/EO/US
Bernhard Raaf et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☐ has been transmitted by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ A copy of the International Search Report (PCT/ISA/210).
8. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☒ are transmitted herewith (required only if not transmitted by the International Bureau).
   - b. ☐ have been transmitted by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
9. ☒ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☒ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☒ Certificate of Mailing by Express Mail
20. ☒ Other items or information:

Submission of Drawings - Figures 1-14 on twelve sheets

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 09/937027	INTERNATIONAL APPLICATION NO. PCT/EP00/02440	ATTORNEY'S DOCKET NUMBER 112740-283

21. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

- ☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1,000.00**
- ☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but Internation Search Report prepared by the EPO or JPO **$860.00**
- ☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**
- ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**
- ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				**$860.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).				**$0.00**	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	9 - 20 =	0	x $18.00	**$0.00**	
Independent claims	2 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$860.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable)** ☐				**$0.00**	
SUBTOTAL =				**$860.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$860.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$860.00**	
				Amount to be: refunded	$
				charged	$

☒ A check in the amount of **$860.00** to cover the above fees is enclosed.

☐ Please charge my Deposit Account No. in the amount of to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

William E. Vaughan (Reg. No. 39,056)
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SIGNATURE

William E. Vaughan
NAME

39,056
REGISTRATION NUMBER

September 19, 2001
DATE

09/937027

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BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

SUBMISSION OF DRAWINGS

APPLICANTS:	Bernhard Raaf et al.	DOCKET NO.:	112740-283
SERIAL NO:		GROUP ART UNIT:	
FILED:		EXAMINER:	
INTERNATIONAL APPLICATION NO.		PCT/EP00/02440	
INTERNATIONAL FILING DATE:		20 March 2000	
INVENTION:	METHOD AND APPARATUS FOR DATA RATE MATCHING		

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Applicant herewith submits twelve sheets (Figs. 1-14) of drawings for the above-referenced PCT application.

Respectfully submitted,

(Reg. No. 39,056)

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BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

PRELIMINARY AMENDMENT

APPLICANTS:	Bernhard Raaf et al.	DOCKET NO: 112740-283
SERIAL NO:		GROUP ART UNIT:
		EXAMINER:
INTERNATIONAL APPLICATION NO:		PCT/EP00/02440
INTERNATIONAL FILING DATE:		20 March 2000
INVENTION:	METHOD AND APPARATUS FOR DATA RATE MATCHING	

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

In the Specification:

Please replace the Specification of the present application, including the Abstract, with the following Substitute Specification:

SPECIFICATION

TITLE OF THE INVENTION

METHOD AND APPARATUS FOR DATA RATE MATCHING

BACKGROUND OF THE INVENTION

The present invention relates to a method and an apparatus for data transmission with interleaving and subsequent rate matching owing to puncturing or repetition.

Digital communications systems are designed for transmitting data by representing the data in a form which makes it easier to transmit the data via a communication medium. For example, in the case of radio transmissions, the data is transmitted between transmitters and receivers in the communications system in the form of radio signals. In the case of broadband telecommunications networks, the data can be in the form of light, and can be transmitted, for example, via a fiber-optical network between transmitters and receivers in the system.

During data transmission, bits or symbols in the transmitted data may be corrupted, wherein these bits or symbols cannot be determined correctly in the receiver. For this reason, the data communications systems frequently contain ways for ameliorating the corruption of the data which occurs during transmission. One of these ways is to equip transmitters in the system with coders, which use an error control code to code the data before transmission. The error control code is designed such that it adds redundancy to the data in a controlled manner. In the receiver, errors which occur during transmission can be corrected by decoding the error control code, as a result of which the original data is reproduced. The decoding is carried out using an error decoding algorithm, which corresponds to the error control code, which is known to the receiver.

Once the data has been decoded, it is often necessary, for data rate matching, to puncture or to repeat data bits or symbols from a block of coded data, before such data is transmitted. In this context, the term puncturing refers to a process of removing or deleting bits from a coded data block, with the effect that the punctured bit is not transmitted with this data block. Puncturing could be required, for example, because a multiple access method which is used for transmitting the data via the data-carrying media requires formatting of the data to form blocks of predetermined size, which size does not correspond to the size of the coded data frame.

In order to accommodate the coded data frame in a transport data block having a predetermined size, data bits are therefore either punctured from the coded data frame in order to reduce the size of the coded data block in a situation in which

the coded data frame is larger than the size of the transport data block, or bits in the coded data frame are repeated in a situation in which the coded data frame is smaller than the predetermined size of the transport data block. This will be explained in more detail in the following text using a mobile radio communications system by way of example.

Mobile radio communications systems are equipped with multiple access systems which operate, for example, on the basis of time division multiple access (TDMA) as is used, for example, in the global mobile radio system (GSM), a mobile radio communications standard which is standardized by the European Telecommunications Standard Institution. As an alternative, the mobile radio communications system could be equipped with a multiple access system operating using code division multiple access (CDMA), such as the UMTS system proposed for the third-generation universal mobile telecommunications system.

However, as can be seen, any desired data communications system could be used to represent an exemplary embodiment of the present invention, such as a local data network or a broadband telecommunications network operating using the asynchronous transmission mode. These examples of data communications systems are characterized, in particular, in that data is transmitted as frames, packets or blocks. In the case of a mobile radio communications system, the data is transmitted within radio signals which carry data and represent a predetermined amount of data. Figure 7 shows one example of such a mobile radio communications system.

Figure 7 shows three base stations BS which exchange radio signals with mobile stations MS in a radio coverage area which is formed by cells 1, which are defined by dashed lines 2. The base stations BS are coupled to a network relay system NET. The mobile stations MS and the base stations BS exchange data by using radio signals, in that they transmit radio signals 4 between antennas 6, which are coupled to the mobile stations MS and to the base stations BS. The data is transmitted between the mobile stations MS and the base stations BS using a data communications apparatus, in which the data is transformed into radio signals 4,

which are transmitted to the receiving antenna 6, which identifies the radio signals. The data is reproduced from the radio signals by the receiver. The present invention can, in this case, be used both in the uplink direction (MS BS) and in the downlink direction (BS MS).

Figure 8 shows an example of a data communications apparatus which forms a radio communication path between one of the mobile stations MS and one of the base stations BS, with parts which also appear in Figure 7 having identical numerical designations. In Figure 8, a data source 10 produces data frames 8 at a rate which is governed by the type of data produced by the source. The data frames 8 produced by the source 10 are supplied to a rate converter 12 which converts the data frames 8 to form transport data blocks 14. The transport data blocks 14 are designed such that they are of essentially the same size, with a predetermined size and an amount of data which can be carried by frames in data-carrying radio signals, via which data is transmitted by a radio interface which is formed from a pair including a transmitter 18 and a receiver 22.

The transport data block 14 is supplied to a radio access processor 16, which controls the sequence of transmission of the transport data block 14 via the radio access interface. The transport data block 14 is supplied at an appropriate time by the radio access processor 16 to a transmitter 18, which converts the transport data block to the frame of data-carrying radio signals, which are transmitted in a time interval which is allocated to that transmitter in order to transmit the radio signals. In the receiver 22, a receiver antenna 6'' identifies the radio signals and carries out downward conversion and reproduction of the data frame, and this is supplied to a radio access sequence control reversing apparatus 24. The radio access sequence control reversing apparatus 24 supplies the received data transport block to a frame conversion reversing apparatus 26 which is controlled by the multiple access sequence control reversing apparatus 24, and is supplied via a conductor 28. The rate conversion reversing apparatus 26 then supplies a representation of the reproduced data frame 8 to a destination or sink for the data frame 8 which is represented by the block 30.

The rate converter 12 and the rate conversion reversing apparatus 26 are designed such that, as far as possible, they utilize the data-carrying capacity available in the transport data block 14 optimally. According to an exemplary embodiment of the present invention, this is done via the rate matching converter 12, which is used to code the data frame and then puncture or repeat data bits or symbols which are selected from the coded data frame, with the effect of producing a transport data block which fits into the data blocks 14. The rate converter 12 has a coder and a puncturer. The data frame 8 which is supplied to the coder is coded, in order to produce a coded data frame which is supplied to the puncturer. The coded data frame is then punctured by the puncturer, in order to produce the transport data block 14. Depending on the embodiment variant, puncturing of frames can be used both in the uplink direction and in the downlink direction.

GB 2296165 A discloses a multiplex communications system, which has puncturing and interleaving.

Those skilled in the art are familiar with the fact that one effect of puncturing a coded data frame is that the probability of correct reproduction of the original data is reduced. Furthermore, the performance of known error control codes and the known decoders of these error control codes is best when the errors which occur during the transmission of the data are caused by Gaussian noise, since this has the effect that the errors are distributed independently throughout the transport data block. When a coded data frame is intended to be punctured, the positions in the coded data frame at which bits are punctured should be separated as far as possible from one another. To this extent, the puncturing positions should be distributed uniformly throughout the data frames. Since errors during transmission frequently occur in bursts, particularly in the case of radio communications systems which do not use interleaving, and since the repetitions of bits are not intended to particularly improve the quality just in a certain region of the data frame but should be as uniform as possible, positions in a coded or uncoded data frame in which data bits are intended to be repeated should be arranged similarly so that they are uniformly separated from one another throughout the entire data frame.

Known methods for selecting positions of bits or symbols which are intended to be punctured in a coded data frame include the division of the number of bits or symbols in a frame by the number of bits or symbols which are intended to be punctured, and the selection of positions with integer values corresponding to the division. In a situation in which the number of bits to be punctured is not an integer division of the number of bits in the data frame, this does not, however, lead to uniform spacings between the punctured positions, thus resulting in the disadvantage that the distance between certain punctured positions is less than this corresponding integer and, in some cases, the punctured positions are even located alongside one another.

In order to describe the complex present invention, the narrower technical field of the present invention and the problems that occur in this case will be briefly explained in the following text with reference to Figures 1 to 6 and 9 but, at least partially, also result from the state of standardization for the 3rd mobile radio generation (UMTS (Universal Mobile Telecommunications System)) prior to the present invention, which is specified in particular in the following document: S1.12 v0.0.1, 3GPP FDD, Multiplexing, channel coding and interleaving description.

The interleaving within a transport multiplexing method is frequently carried out in two steps. The various solutions for carrying out the puncturing/repetition have various consequences if the puncturing is carried out after the first interleaver, as is envisaged from the UMTS system. A second interleaver is now also used in the UMTS system, and is arranged after the physical channel segmentation and before the physical channel mapping (see Figure 1). Although this interleaver results in an improvement in the transmitted bits being distributed as uniformly as possible, it has no influence, however, on the distribution of the punctured/repeated bits, and therefore will not be discussed any further for the purposes of the present invention.

Figure 1 shows the use of an FS-MIL (FS-Multistage Interleaver) as an interleaver in the uplink path multiplexing method in conjunction with a known rate matching algorithm proposed for UMTS.

As an example, let us consider a situation in which layer 2 results in a transport block with 160 bits on a transport channel with a transmission interval of 80 ms. This bit sequence also can be described as a data frame, or as a sequence of data frames. As such, after the first interleaver, (first interleaving), the data is interleaved over eight radio frames (often also referred to as "frames" or "columns" in the following text) (see Figure 2). In this case, the interleaving includes the bits being read line-by-line, and the bits being read column-by-column with subsequent column randomizing (columns being interchanged).

A first aim of a good puncturing algorithm is to distribute punctured bits as uniformly as possible over the bit positions in their original sequence. This was also the critical principle which was used for the definition of the puncturing algorithm for UMTS, as is described, for example, in the abovementioned Specification S1.12. This is best done by puncturing every n-th bit or, in some cases, every (n+first) bit if the puncturing rates are not integral.

A second aim is to puncture the various frames (in the following text, frames are also often referred to as columns or radio frames) with equal frequency, and hence also to distribute the punctured bits uniformly over all the frames, and also to achieve uniform puncturing in the various frames. The expressions puncturing or repetition of a column (for the frame) also refer to the puncturing or repetition of an element, in particular of a bit in the column (the frame).

Let us now assume that four bits are intended to be punctured in each frame (radio frame) in order to produce a balance for the requirements for the quality of the service of this transport channel together with other channels. The result of the rate matching algorithm - previously intended for the UMTS system - is to puncture the bits 4, 9, 14 and 19 (index starts at 0, counting based on the sequence of the bits after the first interleaving) in each frame (radio frame). In Figure 2, a punctured bit is illustrated in bold text. In consequence, eight adjacent bits are punctured, and this, as explained above, is undesirable. The first aim mentioned above is not achieved to a satisfactory extent.

One procedure to avoid this problem would be to shift the puncturing pattern in each frame. Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_l is the index of the punctured/repeated bit, k is the frame number and K is the number of interleaved frames.

Let us then consider the situation where $N_i > N_c$, that is to say puncturing. In the above example, $N_i=20$, $N_c=16$, $m_1=4$, $m_2=9$, $m_3=14$, $m_4=19$, $k=1...7$ and $K=8$. A shift in the positions of the bits to be punctured in order to avoid the abovementioned problem can then be described by the following formula:

$m_{jshift} = (m_j + k*\lceil N_c/(N_c-N_c)/K \rceil) \bmod N_i$, where $\lceil\ \rceil$ refers to round up.

The positions of the bits to be punctured resulting from this formula are illustrated, for the above example, in Figure 3.

As can be seen from Figure 3, the puncturing of adjacent bits is admittedly avoided to a certain extent, but this results in a cyclic effect or edge effect, that is to say for example, bits 43 and 44 are punctured, which, as explained above, is undesirable. The first aim mentioned above is accordingly once again not achieved to a satisfactory extent.

If the puncturing ratio is low, the probability of puncturing adjacent bits decreases. Figure 4 shows an example with 10% puncturing. As can be seen from Figure 4, some adjacent bits (bit 91 and bit 92) are still punctured, however, which results in a reduction in performance. Once again, the first aim mentioned above is not achieved to a satisfactory extent.

As an alternative to a described rate matching algorithm, it is proposed that the first interleaver (first interleaving) be optimized such that the puncturing no longer requires the described rate matching algorithm. An optimized first interleaver should reorder the bits such that adjacent bits are separated. The puncturing, accordingly can be carried out simply by removing successive bits after the interleaving process. The following options will be explained in more detail with reference to the scenario illustrated in Figure 5.

The four blocks on TrCH A are interleaved together, and the rate matching is then carried out. When puncturing is carried out, successive bits are removed in each frame. It is therefore highly improbable that punctured bits would be adjacent in a frame, with respect to their position before the interleaving process, that is to say after coding. However, there is no guarantee that punctured bits would not be adjacent in different frames after the coding process. In consequence, a reduction in performance could occur when using this approach.

The method explained in the following text with reference to Figure 6 could be used to solve the problem explained with reference to Figure 4, in which method the puncturing pattern applied to a frame is also applied, after shifting, to other frames, with the shifted patterns being applied to frames before the interleaving process. Figure 6 shows a puncturing pattern for the bit sequence example which already has been explained with reference to Figure 3. The illustration shows that no puncturing of adjacent bits occurs, at least in this example. The reduction in performance resulting from puncturing therefore should be avoided in this case.

In fact, there is no need to carry out the above rate matching before the column randomization (column interchanging). Rate matching equivalent to this can be carried out after the column randomization by taking account of the column randomization rules, and this can be achieved just by replacing the initial column-specific offset value e_{offset}, which describes this shift in the application of the puncturing pattern by a simple formula. The offset value is not calculated on the basis of the column number after column randomization, but the column number before the column randomization, and this can be calculated using the inverse column interchanging rule. Furthermore, e_{offset} can be used not just for puncturing, but also for repetition. Repetition bits can, thus, be positioned more uniformly.

The following text once again shows, in summary form, that the previously proposed solutions, that is to say the proposed puncturing/repetition patterns, are still not always optimum in all cases.

In the introduction, it was shown with reference to Figure 2 and by analysis by way of example of a situation in which layer 2 provides a transport block with

160 bits on a transport channel with a transmission interval of 80 ms, and subject to the precondition that four bits should be punctured in each frame, that eight adjacent bits are punctured, which is obviously undesirable. The first aim mentioned above is not achieved to a satisfactory extent.

The proposal as shown in Figures 3 and 4 was to shift the puncturing pattern in each frame. Once again, as shown, this led to puncturing of adjacent bits (bits 43 and 44 as well as bits 91 and 92). The first aim mentioned above is not achieved to a satisfactory extent.

The proposal as shown in Figure 6 provides for the use of shifted puncturing patterns after the interleaving process, in which case the column-specific shifts were determined on the basis of analyses before column interchanging. In this case, this does not lead to any adjacent punctured bits in this example.

However, in a method as shown in Figure 6, there are always still situations in which adjacent bits are punctured, depending on the puncturing rate. Figure 9 shows, by way of example, the situation N_i=16, N_c=14, m_1=4, m_2=14, k=1...7 and K=8. For the sake of simplicity, Figures 9 and 10 show only the area before interleaving, in which, however, those bit positions which are punctured after interleaving are illustrated by marking them in bold print. As can be seen, the adjacent bits 31 and 32 and 95-96 are punctured, which is obviously undesirable. Once again, the first aim mentioned above is not achieved to a satisfactory extent.

If, in contrast, only every n-th bit were to be punctured with respect to the original sequence after the interleaver process, then the second aim cannot always be achieved adequately. Let us assume, for example, 80-ms interleaving (as in Figure 9) and a puncturing rate of 1:6. Puncturing every sixth bit would result in only the columns 0, 2, 4, 6 being punctured, but not the columns 1, 3, 5, 7, which is, of course, undesirable and is not consistent with the second aim. In contrast, the first aim would be achieved to a satisfactory extent.

Against this background, the present invention is directed toward reducing these disadvantages of the prior art.

SUMMARY OF THE INVENTION

Accordingly, in the embodiment of the present invention, a method is provided for data rate matching, wherein the method includes the steps of: (a) distributing data to be transmitted in the form of bits via a first interleaver to a set of K frames; (b) carrying out a puncturing or repetition method for data rate matching after interleaving; and (c) varying a distance between punctured or repeated bits with regard to the sequence of the bits before the first interleaver, for puncturing or repeating the same number of bits in each frame, with the separation being defined by the following relationship: $q-1 \leq$ distance $\leq q + \mathrm{lcd}(q,K) +1$, where $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and $\mathrm{lcd}(q, K)$:= highest common denominator of q and K.

In an embodiment, the following relationship is also valid when the puncturing rate or the repetition rate is equal to 1/K: $q-1 \leq$ distance $\leq q + \mathrm{lcd}(q,K) +1$, where: $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and $\mathrm{lcd}(q, K)$:= highest common denominator of q and K.

In an embodiment, punctured or repeated bits which are adjacent to the sequence of bits before the first interleaver are obtained by a method which includes the steps of: puncturing or repetition with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q; varying the distance to q-1 or q+1 between adjacent punctured or repeated bits, if the number of punctured or repeated bits in a frame would exceed the number of punctured or repeated bits in another frame by more than one, and if the puncturing or repetition were carried out with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q; and continuing with the step of puncturing if any further bits need to be punctured or repeated.

In an embodiment, a puncturing or repetition process is carried out in such a manner that the puncturing or repetition pattern used within a frame is also shifted and used within further frames in the set of frames.

In an embodiment, the shift $V(k) = S(k) + T(k) * Q$ in the use of the puncturing or repetition pattern to the frame k can be produced via the steps of: calculating a mean puncturing distance q=, in which case: $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ referes to rounding down and $|\ |$ refers to absolute value, and in which case: N_i := the number of bits after rate matching, and N_c := the number of bits before rate matching; calculating Q, in which case: $Q := ((\lfloor N_c/(|N_i-N_c|)\rfloor) \text{ div } K$; if q is even, then q is set to q - lcd(q, K)/K where lcd(q, K):= the highest common denominator of q and K; - a variable i is set to zero; and repeating the following steps as long as $i \leq K-1$: $S(R_K(\lceil i*q\rceil \bmod K)) = (\lceil i*q\rceil \text{ div } K)$, where $\lceil\ \rceil$ referes to rounding; $T((R_K(\lceil i*q\rceil \bmod K)) = i$, where $R_K(k)$ reverses the interleaver; and i becomes i + 1.

In an embodiment, the shift $V(k) = S(k)$ of the use of the puncturing and repetition pattern to the frame k can be produced via the steps of: calculating a mean puncturing distance q, in which case: $q := (\lfloor N_c/(|N_i-N_c|)\rfloor)$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and in which case: N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and if q is even, then q is set to q - lcd(q, K)/K, where lcd(q, K):= the highest common denominator of q and K; - a variable i is set to zero; and repeating the following steps as long as $i \leq K-1$: $S(R_K(\lceil i*q\rceil \bmod K)) = (\lceil i*q\rceil \text{ div } K)$, where $\lceil\ \rceil$ refers to rounding up; $R_K(k)$, where $R_K(k)$ reverses the interleaver; i becomes i + 1.

In an embodiment, bits which are to be punctured or to be repeated or produced via a method which includes the steps of: determing the integer component q of the mean puncturing distance using $q := (\lfloor N_c/(|N_i-N_c|)\rfloor)$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to value, and in which case: N_i := the number of bits after rate matching, and N_c := the number of bits before rate matching; selecting a bit to be punctured or to be repeated in a first column; selecting the next bit to be punctured or to be repeated in the next frame, starting from the last bit to

be punctured or to be repeated in the previous frame by selecting the next bit at the distance q, with respect to the original sequence, starting with this last bit to be punctured or to be repeated, providing this does not lead to a frame being punctured or repeated twice, or else by selecting a bit with a distance which has been changed from q to q-1 or q+1 for puncturing or repetition; and repeating the step of selecting the next bit until all columns have been punctured or repeated once.

In an embodiment, bits in a first frame are punctured or repeated in accordance with a predetermined puncturing pattern or repetition pattern, and in order to select further bits to be punctured or to be repeated, the puncturing pattern or repetition pattern shifted and is applied to further frames, with the shift in the application of the puncturing pattern or repetition pattern to a further frame corresponding to the shift of the bit, chosen in the step of selecting the next bit in the further frame with respect to the bit chosen in the step of selecting a bit.

In a further embodiment of the present invention, a data rate matching apparatus is provided which includes: means for distributing data to be transmitted in the form of bits via a first interleaver to a set of K frames; means for carrying out a puncturing or repetition method for data rate matching after interleaving; and means for varying a distance between punctured or repeated bits with regard to the sequence of the bits before the first interleaver, for puncturing or repeating the same number of bits in each frame, with the separation being defined by the following relationship: $q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1$, where $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and lcd(q, K) := highest common denominator of q and K.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a simplified flowchart with an interleaver before rate matching (prior art).

Figure 2 shows interleaving and puncturing patterns for puncturing of four bits per frame (prior art).

Figure 3 shows interleaving and shifted puncturing patterns for puncturing of four bits per frame (prior art).

Figure 4 shows interleaving and shifted puncturing patterns for puncturing with a puncturing ratio of 10% (prior art).

Figure 5 shows a simplified illustration of transport channels (prior art).

Figure 6 shows interleaving and shifted puncturing patterns for puncturing of four bits per frame (prior art).

Figure 7 shows a block diagram of a mobile radio communications system (prior art).

Figure 8 shows a block diagram of a data communications arrangement, which forms a path between the mobile station and a base station in the communications network shown in Figure 7 (prior art).

Figure 9 shows puncturing patterns for shifted puncturing patterns for puncturing of two bits per frame (prior art).

Figure 10 shows a simplified illustration of the principle of puncturing which is optimized in accordance with the present invention.

Figure 11 shows a reference table.

Figure 12 shows puncturing patterns for puncturing with a puncturing ratio of 20%.

Figure 13 shows puncturing patterns for puncturing with a puncturing ratio of 1:8.

Figure 14 shows puncturing patterns for puncturing with an odd number of bits to be punctured per frame.

DETAILED DESCRIPTION OF THE INVENTION

As explained above, the second aim cannot always be achieved adequately if every n-th bit were simply to be punctured after interleaving with respect to the original sequence before interleaving. However, the first aim would be achieved to an adequate extent.

In order to achieve both the abovementioned aims to a satisfactory extent, one embodiment of the present invention now provides, in contrast to the uniform puncturing with respect to the original sequence before interleaving, that the puncturing interval be varied at least once, and if necessary a number of times, in order to avoid some columns being preferred for puncturing, while others, on the other hand, are not punctured at all. This is shown in Figure 10. Horizontal arrows (P6) with thin surrounding lines show a puncturing distance of 6, and the horizontal arrow (P5) with thick surrounding lines shows a puncturing distance of 5 in order to avoid puncturing the first column twice. Once each column has been punctured once, the pattern (as shown by the vertical arrows) can be shifted six lines downward in order to define the next bits to be punctured. This obviously corresponds to puncturing of every sixth bit in each column, that is to say it corresponds to the use of a standard rate matching algorithm and to the shifting of puncturing patterns with respect to one another in different columns.

This method will now be described using formulae in the following text.

Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_j is the index of the punctured/repeated bits, k the column or frame number after interleaving and K the number of interleaved columns or frames. The aim is to consider mainly the situation $N_i>N_c$, that is to say puncturing, but the formulae are also applicable to repetition.

In the above example, N_i=20, N_c=16, m_1=4, m_2=9, m_3=14, m_4=19, k=1...7, with k denoting the column or frame number after interleaving, and K=8. A comment is indicated by a prefix "--". The shifts V(k) = S(k) + T(k) * Q in the application of the puncturing or repetition pattern to the frame k can then be determined using the following method:

-- Calculation of the mean puncturing distance

$q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$ -- where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value.

$Q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \operatorname{div} K$

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if q even -- deal with as a special case:

then q = q - lcd(q, K)/K -- where lcd(q, K) refers to the highest common denominator of q and K

-- It should be remembered that lcd easily can be calculated by bit manipulation, since K is a power of 2.

-- For the same reason, calculations with q easily can be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S and T; S represents the shift in the line mod K, and T represents the shift magnitude div K;

S thus represents the shift in the line with respect to q (that is to say mod K) and T the magnitude of the shift with respect to Q (that is to say div K);

for i = 0 to K-1

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$ -- where $\lceil\ \rceil$ referes to rounding up.

$T((R_K(\lceil i*q \rceil \bmod K)) = i$ -- $R_K(k)$ reverses the interleaver,

end for

In an actual implementation, these formulae can be implemented as shown in Figure 11, as a reference table. The table also includes the already described effect of the remapping of the column randomization achieved by $R_K(k)$. S also can be calculated from T, as a further implementation option.

e_{offset} can then be calculated as follows:

$e_{offset}(k) = ((2*S) + 2*T\ Q + 1)*\ y + 1) \bmod 2Nc$

Using $e_{offset}(k)$, e is then preloaded in the rate matching method for UMTS. This choice of e_{offset} obviously results in a shift in the puncturing patterns in the columns relative to one another by the amount S + T * Q.

The following text describes a simplified representation which simply results from the calculation of q and Q not being carried out separately for the remainder in the division by K and the multiple of K, but being combined for both components. In the same way, S and T cannot be calculated separately for q and Q,

but likewise combined. The substitutions q+K*Q --> q and S+Q*T --> S result in the following equivalent representation of the method specified above, with the shift at V(k) in this case being given by: V(k) = S(k). Depending on the details of the implementation, it may be better to carry out one calculation method or the other calculation method or further methods which are likewise equivalent to them.

-- Calculation of the mean puncturing distance

$q := (\lfloor N_c/(|N_i - N_c|) \rfloor)$ -- where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value.

if q even -- deal with as a special case:

then q = q - lcd(q, K)/K -- where lcd(q, K) refers to the highest common denominator of q and K

-- It should be noted that lcd easily can be calculated by bit manipulation, since K is a power of 2.

-- For the same reason, calculations with q easily can be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S(k) for the shift in the column k;

for i = 0 to K-1

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$ -- where $\lceil\ \rceil$ refers to rounding up.

-- $R_K(k)$ reverses the interleaver

end for

e_{offset} can then be calculated as follows:

$e_{offset}(k) = ((2*S) * y + 1) \bmod 2Nc$

Using $e_{offset}(k)$, e is then initialized in advance in the rate matching method.

If the puncturing rate is an odd-numbered fraction, that is to say 1:5 or 1:9, this method likewise produces a puncturing pattern which is optimum with regard to the two aims mentioned above and which would be used directly before the interleaving by the puncturing using the rate matching method. In other situations, adjacent bits are never punctured, but the distance between adjacent punctured bits

may be greater than the others by up to lcd(q,K)+1. This method also can be applied in a corresponding manner to bit repetitions. Although the repetition of adjacent bits does not have such a severe influence on the performance of the error correction codes as is the case when puncturing adjacent bits, it is nevertheless advantageous to distribute repeated bits as uniformly as possible.

The fundamental objective of this method is to achieve a uniform distance between the punctured bits in the original sequence, but taking account of the constraint that the same number of bits must be punctured in the various frames. This is achieved by reducing the puncturing distance by 1 in certain cases. The described method is optimum to the extent that the distance is never reduced by more than 1, and it is reduced only as often as is necessary. This results in the best-possible puncturing pattern subject to the constraints mentioned above.

The following example uses Figure 12 to show puncturing with a puncturing ratio of 1:5. The optimized algorithm obviously not only avoids the puncturing of adjacent bits, but punctured bits are also distributed with the same spacing in the original sequence. In fact, the same characteristics are achieved as if the puncturing were to be carried out directly after the coding and before the interleaving. In the specific case of 1:5 puncturing and, to put this in more general terms, whenever the puncturing rate can be written as a fraction 1:q, where q is an integer and q and K, the number of frames, do not have a common denominator, it can be said that an optimum puncturing pattern is produced despite the use of puncturing after the first interleaver. This puncturing pattern results in the puncturing of every qth bit, in the same way as an optimum puncturing pattern which had been carried out immediately after the coding and before the interleaving.

Puncturing with a puncturing ratio of 1:8 will now be analyzed with reference to Figure 13. Once again, the puncturing of adjacent bits is avoided. In this case, it is impossible to achieve uniformly spaced puncturing, since all the bits in an individual frame would then be punctured, which is completely unacceptable with respect to the second aim. In this case, most of the distances between adjacent

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bits are 7 (only one less than with an optimum distribution). In this case, some distances are greater (every eighth).

If the number N_i of input bits can be divided by K, the rate matching may vary during the transmission time interval. The last frames then have one bit less than the first and, therefore, also have a somewhat lower puncturing rate. For this situation, one embodiment of the present invention provides for the puncturing patterns in the last lines not to be changed. Instead of this, the same puncturing algorithm is used as for the first columns, but without carrying out the last puncturing operation. It can be seen from Figure 14 as an example that 125 input bits are intended to be punctured in such a manner that 104 output bits remain, which are interleaved over eight frames. The last two columns have one input bit less than the first; all the columns have 13 bits, since the last puncturing operation in the last two columns is omitted.

With regard to the aims mentioned above, the method proposed here allows optimized puncturing patterns to be specified when the rate matching is carried out after the first interleaving. The method is simple, requires little computation power and need be carried out only once per frame, and not once per bit. The method is not restricted to radio transmission systems.

Indeed, although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

A method and apparatus for data rate matching, wherein elements to be transmitted are distributed over a number of radio frames via an interleaver and are punctured or repeated, with the puncturing or repetition being carried out in such a manner that, when it is related to the original arrangement of the element before interleaving, the pattern avoids puncturing or repetition of adjacent elements, or of elements which are not far apart from one another.

In the Claims

On page20, cancel line 1, and substitute the following left-hand justified heading therefor:

CLAIMS

Please cancel claims 1-9, without prejudice, and substitute the following claims therefor:

10. A method for data rate matching, the method comprising the steps of:

distributing data to be transmitted in the form of bits via a first interleaver to a set of K frames;

carrying out a puncturing or repetition method for data rate matching after interleaving; and

varying a distance between punctured or repeated bits with regard to the sequence of the bits before the first interleaver, for puncturing or repeating the same number of bits in each frame, with the separation being defined by the following relationship:

$q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1$, where

$q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and

lcd(q, K) := highest common denominator of q and K.

11. A method for data rate matching as claimed in claim 10, wherein the following relationship is also valid when the puncturing rate or the repetition rate is equal to 1/K:

$q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1$, where

$q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and

lcd(q, K) := highest common denominator of q and K.

12. A method for data rate matching as claimed in claim 10, wherein punctured or repeated bits which are adjacent to the sequence of bits before the first interleaver are obtained by a method which comprises the steps of:

puncturing or repetition with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q;

varying the distance to q-1 or q+1 between adjacent punctured or repeated bits, if the number of punctured or repeated bits in a frame would exceed the number of punctured or repeated bits in another frame by more than one, and if the puncturing or repetition were carried out with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q; and

continuing with the step of puncturing if any further bits need to be punctured or repeated.

13. A method for data rate matching as claimed in claims 10, wherein a puncturing or repetition process is carried out in such a manner that the puncturing or repetition pattern used within a frame is also shifted and used within further frames in the set of frames.

14.. A method for data rate matching as claimed in claim 13, wherein the shift $V(k) = S(k) + T(k) * Q$ in the use of the puncturing or repetition pattern to the frame k can be produced via the steps of:

calculating a mean puncturing distance q=, in which case:

$q := (\lfloor N_c/(|N_i - N_c|) \rfloor) \bmod K$, where $\lfloor\ \rfloor$ referes to rounding down and $|\ |$ refers to absolute value, and in which case:

N_i := the number of bits after rate matching, and

N_c := the number of bits before rate matching;

calculating Q, in which case: $Q := ((\lfloor N_c/(|N_i - N_c|) \rfloor) \operatorname{div} K$;

if q is even, then q is set to q - lcd(q, K)/K where lcd(q, K):= the highest common denominator of q and K; - a variable i is set to zero; and

repeating the following steps as long as $i \leq K-1$:

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$, where $\lceil\ \rceil$ referes to rounding;

$T((R_K(\lceil i*q \rceil \bmod K)) = i$, where $R_K(k)$ reverses the interleaver; and

i becomes i + 1.

15. A method for data rate matching as claimed in claim 13, wherein the shift $V(k) = S(k)$ of the use of the puncturing and repetition pattern to the frame k can be produced via the steps of:

calculating a mean puncturing distance q, in which case:

$q := (\lfloor N_c/(|N_i - N_c|) \rfloor)$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value,

and in which case:

N_i := the number of bits after rate matching,

N_c := the number of bits before rate matching; and

if q is even, then q is set to q - lcd(q, K)/K, where lcd(q, K):= the highest common denominator of q and K; - a variable i is set to zero; and

repeating the following steps as long as $i \leq K-1$:

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$, where $\lceil\ \rceil$ refers to rounding up;

$R_K(k)$, where $R_K(k)$ reverses the interleaver; and

i becomes i + 1.

16. A method for data rate matching as claimed in claim 10, wherein bits which are to be punctured or to be repeated are produced via a method which comprises the steps of:

determing the integer component q of the mean puncturing distance using $q := (\lfloor N_c/(|N_i - N_c|)\rfloor)$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to value, and in which case:

N_i := the number of bits after rate matching, and

N_c := the number of bits before rate matching;

selecting a bit to be punctured or to be repeated in a first column;

selecting the next bit to be punctured or to be repeated in the next frame, starting from the last bit to be punctured or to be repeated in the previous frame by selecting the next bit at the distance q, with respect to the original sequence, starting with this last bit to be punctured or to be repeated, providing this does not lead to a frame being punctured or repeated twice, or else by selecting a bit with a distance which has been changed from q to q-1 or q+1 for puncturing or repetition; and

repeating the step of selecting the next bit until all columns have been punctured or repeated once.

17. A method for data rate matching as claimed in claim 16, wherein bits in a first frame are punctured or repeated in accordance with a predetermined puncturing pattern or repetition pattern, and

in order to select further bits to be punctured or to be repeated, the puncturing pattern or repetition pattern shifted and is applied to further frames, with the shift in the application of the puncturing pattern or repetition pattern to a further frame corresponding to the shift of the bit, chosen in the step of selecting the next bit in the further frame with respect to the bit chosen in the step of selecting a bit.

18. A data rate matching apparatus, comprising:

distributing data to be transmitted in the form of bits via a first interleaver to a set of K frames;

carrying out a puncturing or repetition method for data rate matching after interleaving; and

varying a distance between punctured or repeated bits with regard to the sequence of the bits before the first interleaver, for puncturing or repeating the same number of bits in each frame, with the separation being defined by the following relationship:

$$q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1, \text{ where}$$

$q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and

lcd(q, K) := highest common denominator of q and K.

REMARKS

The present amendment makes editorial changes and corrects typographical errors in the specification, which includes the Abstract, in order to conform the specification to the requirements of United States Patent Practice. No new matter is added thereby. Attached hereto is a marked-up version of the changes made to the specification by the present amendment. The attached page is captioned "**Version With Markings To Show Changes Made**".

In addition, the present amendment cancels original claims 1-9 in favor of new claims 10-18. Claims 10-18 have been presented solely because the revisions by red-lining and underlining which would have been necessary in claims 1-9 in order to present those claims in accordance with preferred United States Patent Practice would have been too extensive, and thus would have been too burdensome. The present amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 USC §§103, 102, 103 or 112. Indeed, the cancellation of claims 1-9 does not constitute an intent on the part of the Applicants to surrender any of the subject matter of claims 1-9.

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Early consideration on the merits is respectfully requested.

Respectfully submitted,

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VERSIONS WITH MARKINGS TO SHOW CHANGES MADE

In The Specification:

The Specification of the present application, including the Abstract, has been amended as follows:

SPECIFICATION

TITLE OF THE INVENTION

METHOD AND APPARATUS FOR DATA RATE MATCHING

~~Description~~

~~Data transmission with interleaving and subsequent rate matching by puncturing or repetition~~

BACKGROUND OF THE INVENTION

The present invention relates to a method and an apparatus for data transmission with interleaving and subsequent rate matching owing to puncturing or repetition.

Digital communications systems are designed for transmitting data by representing the data in a form which makes it easier to transmit the data via a communication medium. For example, in the case of radio transmissions, the data is transmitted between transmitters and receivers in the communications system in the form of radio signals. In the case of broadband telecommunications networks, the data can be in the form of light, and can be transmitted, for example, via a fiber-optical network between transmitters and receivers in the system.

During data transmission, bits or symbols in the transmitted data may be corrupted, ~~which means that~~ wherein these bits or symbols cannot be determined correctly in the receiver. For this reason, the data communications systems frequently contain ~~means~~ ways for ameliorating the corruption of the data which occurs during transmission. One of these ~~means~~ ways is to equip transmitters in the system with coders, which use an error control code to code the data before transmission. The error control code is designed such that it adds redundancy to the data~~,~~ in a controlled manner. In the receiver, errors which occur during transmission can be corrected by decoding the error control code, as a result of

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which the original data is reproduced. The decoding is carried out using an error decoding algorithm, which corresponds to the error control code, which is known to the receiver.

Once the data has been decoded, it is often necessary, for data rate matching, to puncture or to repeat data bits or symbols from a block of coded data, before such data is transmitted. In this context, the term puncturing ~~means~~ refers to a process of removing or deleting bits from a coded data block, with the effect that the punctured bit is not transmitted with this data block. Puncturing could be required, for example, because a multiple access method which is used for transmitting the data via the data-carrying media requires formatting of the data to form blocks of predetermined size, which size does not correspond to the size of the coded data frame.

In order to accommodate the coded data frame in a transport data block having a predetermined size, data bits are therefore either punctured from the coded data frame in order to reduce the size of the coded data block in a situation in which the coded data frame is larger than the size of the transport data block, or bits in the coded data frame are repeated~~,~~ in a situation in which the coded data frame is smaller than the predetermined size of the transport data block. This will be explained in more detail in the following text using a mobile radio communications system by way of example~~:~~.

Mobile radio communications systems are equipped with multiple access systems which operate, for example, on the basis of time division multiple access (TDMA) as is used, for example, in the global mobile radio system (GSM), a mobile radio communications standard which is standardized by the European Telecommunications Standard Institution. As an alternative, the mobile radio communications system could be equipped with a multiple access system operating using code division multiple access (CDMA), such as the UMTS system proposed for the third-generation universal mobile telecommunications system.

However, as can be seen, any desired data communications system could be used to represent an exemplary embodiment of the present invention, such as a local

data network or a broadband telecommunications network operating using the asynchronous transmission mode. These examples of data communications systems are characterized, in particular, in that data is transmitted as frames, packets or blocks. In the case of a mobile radio communications system, the data is transmitted within radio signals which carry data and represent a predetermined amount of data. Figure 7 shows one example of such a mobile radio communications system.

Figure 7 shows three base stations BS which exchange radio signals with mobile stations MS in a radio coverage area which is formed by cells 1, which are defined by dashed lines 2. The base stations BS are coupled to a network relay system NET. The mobile stations MS and the base stations BS exchange data by using radio signals, in that they transmit radio signals 4 between antennas 6, which are coupled to the mobile stations MS and to the base stations BS. The data is transmitted between the mobile stations MS and the base stations BS using a data communications apparatus, in which the data is transformed into radio signals 4, which are transmitted to the receiving antenna 6, which identifies the radio signals. The data is reproduced from the radio signals by the receiver. The present invention can, in this case, be used both in the uplink direction (MS BS) and in the downlink direction (BS MS).

Figure 8 shows an example of a data communications apparatus which forms a radio communication path between one of the mobile stations MS and one of the base stations BS, with parts which also appear in Figure 7 having identical numerical designations. In Figure 8, a data source 10 produces data frames 8 at a rate which is governed by the type of data produced by the source. The data frames 8 produced by the source 10 are supplied to a rate converter 12~~,~~ which converts the data frames 8 to form transport data blocks 14. The transport data blocks 14 are designed such that they are of essentially the same size, with a predetermined size and an amount of data which can be carried by frames in data-carrying radio signals, via which data is transmitted by a radio interface which is formed from a pair ~~comprising~~ including a transmitter 18 and a receiver 22.

The transport data block 14 is supplied to a radio access processor 16, which controls the sequence of transmission of the transport data block 14 via the radio access interface. The transport data block 14 is supplied at an appropriate time by the radio access processor 16 to a transmitter 18, which converts the transport data block to the frame of data-carrying radio signals, which are transmitted in a time interval which is allocated to that transmitter~~,~~ in order to transmit the radio signals. In the receiver 22, a receiver antenna 6'' identifies the radio signals and carries out downward conversion and reproduction of the data frame, and this is supplied to a radio access sequence control reversing apparatus 24. The radio access sequence control reversing apparatus 24 supplies the received data transport block to a frame conversion reversing apparatus 26 which is controlled by the multiple access sequence control reversing apparatus 24, and is supplied via a conductor 28. The rate conversion reversing apparatus 26 then supplies a representation of the reproduced data frame 8 to a destination or sink for the data frame 8~~,~~ which is represented by the block 30.

The rate converter 12 and the rate conversion reversing apparatus 26 are designed such that, as far as possible, they utilize the data-carrying capacity available in the transport data block 14 optimally. According to an exemplary embodiment of the present invention, this is done ~~by means of~~ via the rate matching converter 12, which is used to code the data frame and then puncture or repeat data bits or symbols which are selected from the coded data frame, with the effect of producing a transport data block which fits into the data blocks 14. The rate converter 12 has a coder and a puncturer. The data frame 8 which is supplied to the coder is coded, in order to produce a coded data frame which is supplied to the puncturer. The coded data frame is then punctured by the puncturer, in order to produce the transport data block 14. Depending on the embodiment variant, puncturing of frames can be used both in the uplink direction and in the downlink direction.

GB 2296165 A discloses a multiplex communications system, which has puncturing and interleaving.

Those skilled in the art are familiar with the fact that one effect of puncturing a coded data frame is that the probability of correct reproduction of the original data is reduced. Furthermore, the performance of known error control codes and the known decoders of these error control codes is best when the errors which occur during the transmission of the data are caused by Gaussian noise, since this has the effect that the errors are distributed independently throughout the transport data block. When a coded data frame is intended to be punctured, the positions in the coded data frame at which bits are punctured should be separated as far as possible from one another. To this extent, the puncturing positions should be distributed uniformly throughout the data frames. Since errors during transmission frequently occur in bursts, particularly in the case of radio communications systems which do not use interleaving, and since the repetitions of bits are not intended to particularly improve the quality just in a certain region of the data frame but should be as uniform as possible, positions in a coded or uncoded data frame in which data bits are intended to be repeated should be arranged similarly so that they are uniformly separated from one another throughout the entire data frame.

Known methods for selecting positions of bits or symbols which are intended to be punctured in a coded data frame include the division of the number of bits or symbols in a frame by the number of bits or symbols which are intended to be punctured, and the selection of positions with integer values corresponding to the division. In a situation in which the number of bits to be punctured is not an integer division of the number of bits in the data frame, this does not, however, lead to uniform spacings between the punctured positions, thus resulting in the disadvantage that the distance between certain punctured positions is less than this corresponding integer and, in some cases, the punctured positions are even located alongside one another.

In order to describe the complex <u>present</u> invention, the narrower technical field of the <u>present</u> invention and the problems that occur in this case will be briefly explained in the following text with reference to Figures 1 to 6 and 9 but, at least partially, also result from the state of standardization for the 3rd mobile radio

generation (UMTS (Universal Mobile Telecommunications System)) prior to the present invention, which is specified in particular in the following document: S1.12 v0.0.1, 3GPP FDD, Multiplexing, channel coding and interleaving description.

The interleaving within a transport multiplexing method is frequently carried out in two steps. The various solutions for carrying out the puncturing/repetition have various consequences if the puncturing is carried out after the first interleaver, as is envisaged from the UMTS system. A second interleaver is now also used in the UMTS system, and is arranged after the physical channel segmentation and before the physical channel mapping (see Figure 1). Although this interleaver results in an improvement in the transmitted bits being distributed as uniformly as possible, it has no influence, however, on the distribution of the punctured/repeated bits, and ~~will~~ therefore will not be discussed any further for the purposes of ~~this~~ the present invention.

Figure 1 shows the use of an FS-MIL (FS-Multistage Interleaver) as an interleaver in the uplink path multiplexing method~~,~~ in conjunction with a known rate matching algorithm proposed for UMTS.

As an example, let us consider a situation in which layer 2 results in a transport block with 160 bits on a transport channel with a transmission interval of 80 ms. This bit sequence ~~can~~ also can be described as a data frame, or as a sequence of data frames. ~~This means that~~ As such, after the first interleaver, (first interleaving), the data is interleaved over eight radio frames (often also referred to as "frames" or "columns" in the following text) (see Figure 2). In this case, the interleaving ~~comprises~~ includes the bits being read line-by-line, and the bits being read column-by-column with subsequent column randomizing (columns being interchanged).

A first aim of a good puncturing algorithm is to distribute punctured bits as uniformly as possible over the bit positions in their original sequence. This was also the critical principle which was used for the definition of the puncturing algorithm for UMTS, as is described, for example, in the abovementioned

Specification S1.12. This is best done by puncturing every n-th bit or, in some cases, every (n+first) bit if the puncturing rates are not integral.

A second aim is to puncture the various frames (in the following text, frames are also often referred to as columns or radio frames) with equal frequency, and hence also to distribute the punctured bits uniformly over all the frames, and also to achieve uniform puncturing in the various frames. The expressions puncturing or repetition of a column (for the frame) also ~~mean~~ <u>refer to</u> the puncturing or repetition of an element, in particular of a bit in the column (the frame).

Let us now assume that four bits are intended to be punctured in each frame (radio frame) in order to produce a balance for the requirements for the quality of the service of this transport channel together with other channels. The result of the rate matching algorithm - previously intended for the UMTS system - is to puncture the bits 4, 9, 14 and 19 (index starts at 0, counting based on the sequence of the bits after the first interleaving) in each frame (radio frame). In Figure 2, a punctured bit is illustrated in bold text. In consequence, eight adjacent bits are punctured, and this, as explained above, is undesirable. The first aim mentioned above is not achieved to a satisfactory extent.

One procedure to avoid this problem would be to shift the puncturing pattern in each frame. Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_l is the index of the punctured/repeated bit, k is the frame number and K is the number of interleaved frames.

Let us then consider the situation where $N_i>N_c$, that is to say puncturing. In the above example, $N_i=20$, $N_c=16$, $m_1=4$, $m_2=9$, $m_3=14$, $m_4=19$, $k=1...7$ and $K=8$. A shift in the positions of the bits to be punctured in order to avoid the abovementioned problem can then be described by the following formula:

$m_{jshift} = (m_j + k*\lceil N_c/(N_c-N_c)/K \rceil) \bmod N_i$, where $\lceil\ \rceil$ refers to round up.

The positions of the bits to be punctured resulting from this formula are illustrated, for the above example, in Figure 3.

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As can be seen from Figure 3, the puncturing of adjacent bits is admittedly avoided to a certain extent, but this results in a cyclic effect or edge effect, that is to say for example, bits 43 and 44 are punctured, which, as explained above, - is undesirable. The first aim mentioned above is accordingly once again not achieved to a satisfactory extent.

If the puncturing ratio is low, the probability of puncturing adjacent bits decreases. Figure 4 shows an example with 10% puncturing. As can be seen from Figure 4, some adjacent bits (bit 91 and bit 92) are still punctured, however, which results in a reduction in performance. Once again, the first aim mentioned above is not achieved to a satisfactory extent.

As an alternative to a described rate matching algorithm, it is proposed that the first interleaver (first interleaving) be optimized such that the puncturing no longer requires the described rate matching algorithm. An optimized first interleaver should reorder the bits such that adjacent bits are separated. The puncturing, ~~can~~ accordingly can be carried out simply by removing successive bits after the interleaving process. ~~However,the~~ The following ~~two~~ options~~, which~~ will be explained in more detail with reference to the scenario illustrated in Figure 5.

The four blocks on TrCH A are interleaved together, and the rate matching is then carried out. When puncturing is carried out, successive bits are removed in each frame. It is therefore highly improbable that punctured bits would be adjacent in a frame, with respect to their position before the interleaving process, that is to say after coding. However, there is no guarantee that punctured bits would not be adjacent in different frames after the coding process. In consequence, a reduction in performance could occur when using this approach.

The method explained in the following text with reference to Figure 6 could be used to solve the problem explained with reference to Figure 4, in which method the puncturing pattern applied to a frame is also applied, after shifting, to other frames, with the shifted patterns being applied to frames before the interleaving process. Figure 6 shows a puncturing pattern for the bit sequence example which ~~has~~ already has been explained with reference to Figure 3. The illustration shows

that no puncturing of adjacent bits occurs, at least in this example. The reduction in performance resulting from puncturing ~~should~~ therefore should be avoided in this case.

In fact, there is no need to carry out the above rate matching before the column randomization (column interchanging). Rate matching equivalent to this can be carried out after the column randomization by taking account of the column randomization rules, and this can ~~easily~~ be achieved just by replacing the initial column-specific offset value e_{offset}, which describes this shift in the application of the puncturing pattern by a simple formula. The offset value is not calculated on the basis of the column number after column randomization, but the column number before the column randomization, and this can be calculated using the inverse column interchanging rule. Furthermore, e_{offset} can be used not ~~used~~ just for puncturing, but also for repetition. Repetition bits can, thus, ~~also~~ be positioned more uniformly.

The following text once again shows, in summary form, that the previously proposed solutions, that is to say the proposed puncturing/repetition patterns, are still not always optimum in all cases.

In the introduction, it was shown with reference to Figure 2 and by analysis by way of example of a situation in which layer 2 provides a transport block with 160 bits on a transport channel with a transmission interval of 80 ms, and subject to the precondition that four bits should be punctured in each frame, that eight adjacent bits are punctured, which is obviously undesirable. The first aim mentioned above is not achieved to a satisfactory extent.

The proposal as shown in Figures 3 and 4 was to shift the puncturing pattern in each frame. Once again, as shown, this led to puncturing of adjacent bits (bits 43 and 44 as well as bits 91 and 92). The first aim mentioned above is not achieved to a satisfactory extent.

The proposal as shown in Figure 6 provides for the use of shifted puncturing patterns after the interleaving process, in which case the column-specific shifts were

determined on the basis of analyses before column interchanging. In this case, this does not lead to any adjacent punctured bits in this example.

However, in a method as shown in Figure 6, there are always still situations in which adjacent bits are punctured, depending on the puncturing rate. Figure 9 shows, by way of example, the situation N_i=16, N_c=14, m_1=4, m_2=14, k=1...7 and K=8. For the sake of simplicity, Figures 9 and 10 show only the area before interleaving, in which, however, those bit positions which are punctured after interleaving are illustrated by marking them in bold print. As can be seen, the adjacent bits 31 and 32 and 95-96 are punctured, which is obviously undesirable. Once again, the first aim mentioned above is not achieved to a satisfactory extent.

If, in contrast, only every n-th bit were to be punctured with respect to the original sequence after the interleaver process, then the second aim cannot always be achieved adequately. Let us assume, for example, 80-ms interleaving (as in Figure 9) and a puncturing rate of 1:6. Puncturing every sixth bit would result in only the columns 0, 2, 4, 6 being punctured, but not the columns 1, 3, 5, 7, which is, of course, undesirable and is not consistent with the second aim. In contrast, the first aim would be achieved to a satisfactory extent.

Against this background, the present invention is ~~based on the object of~~ directed toward reducing these disadvantages of the prior art.

SUMMARY OF THE INVENTION

~~This object is achieved by the features of the independent claims. Developments of the invention can be found in the dependent claims.~~

~~Embodiments of the present invention will not be described just by way of example with reference to the attached drawings, in which~~

Accordingly, in the embodiment of the present invention, a method is provided for data rate matching, wherein the method includes the steps of: (a) distributing data to be transmitted in the form of bits via a first interleaver to a set of K frames; (b) carrying out a puncturing or repetition method for data rate matching after interleaving; and (c) varying a distance between punctured or repeated bits with regard to the sequence of the bits before the first interleaver, for

puncturing or repeating the same number of bits in each frame, with the separation being defined by the following relationship: $q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1$, where $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and $\text{lcd}(q, K)$:= highest common denominator of q and K.

In an embodiment, the following relationship is also valid when the puncturing rate or the repetition rate is equal to 1/K: $q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1$, where $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and $\text{lcd}(q, K)$:= highest common denominator of q and K.

In an embodiment, punctured or repeated bits which are adjacent to the sequence of bits before the first interleaver are obtained by a method which includes the steps of: puncturing or repetition with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q; varying the distance to q-1 or q+1 between adjacent punctured or repeated bits, if the number of punctured or repeated bits in a frame would exceed the number of punctured or repeated bits in another frame by more than one, and if the puncturing or repetition were carried out with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q; and continuing with the step of puncturing if any further bits need to be punctured or repeated.

In an embodiment, a puncturing or repetition process is carried out in such a manner that the puncturing or repetition pattern used within a frame is also shifted and used within further frames in the set of frames.

In an embodiment, the shift $V(k) = S(k) + T(k) * Q$ in the use of the puncturing or repetition pattern to the frame k can be produced via the steps of: calculating a mean puncturing distance q=, in which case: $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ referes to rounding down and $|\ |$ refers to absolute value, and in which

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case: N_i := the number of bits after rate matching, and N_c := the number of bits before rate matching; calculating Q, in which case: $Q := ((\lfloor N_c/(|N_i - N_c|)\rfloor)$ div K; if q is even, then q is set to q - lcd(q, K)/K where lcd(q, K):= the highest common denominator of q and K; - a variable i is set to zero; and repeating the following steps as long as $i \leq K-1$: $S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$, where $\lceil\ \rceil$ referes to rounding; $T((R_K(\lceil i*q \rceil \bmod K)) = i$, where $R_K(k)$ reverses the interleaver; and i becomes i + 1.

In an embodiment, the shift V(k) = S(k) of the use of the puncturing and repetition pattern to the frame k can be produced via the steps of: calculating a mean puncturing distance q, in which case: $q := (\lfloor N_c/(|N_i - N_c|)\rfloor)$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and in which case: N_i := the number of bits after rate matching, N_c := the number of bits before rate matching; and if q is even, then q is set to q - lcd(q, K)/K, where lcd(q, K):= the highest common denominator of q and K; - a variable i is set to zero; and repeating the following steps as long as $i \leq K-1$: $S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$, where $\lceil\ \rceil$ refers to rounding up; $R_K(k)$, where $R_K(k)$ reverses the interleaver; and i becomes i + 1.

In an embodiment, bits which are to be punctured or to be repeated or produced via a method which includes the steps of: determing the integer component q of the mean puncturing distance using $q := (\lfloor N_c/(|N_i - N_c|)\rfloor)$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to value, and in which case: N_i := the number of bits after rate matching, and N_c := the number of bits before rate matching; selecting a bit to be punctured or to be repeated in a first column; selecting the next bit to be punctured or to be repeated in the next frame, starting from the last bit to be punctured or to be repeated in the previous frame by selecting the next bit at the distance q, with respect to the original sequence, starting with this last bit to be punctured or to be repeated, providing this does not lead to a frame being punctured or repeated twice, or else by selecting a bit with a distance which has been changed from q to q-1 or q+1 for puncturing or repetition; and repeating the step of selecting the next bit until all columns have been punctured or repeated once.

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In an embodiment, bits in a first frame are punctured or repeated in accordance with a predetermined puncturing pattern or repetition pattern, and in order to select further bits to be punctured or to be repeated, the puncturing pattern or repetition pattern shifted and is applied to further frames, with the shift in the application of the puncturing pattern or repetition pattern to a further frame corresponding to the shift of the bit, chosen in the step of selecting the next bit in the further frame with respect to the bit chosen in the step of selecting a bit.

In a further embodiment of the present invention, a data rate matching apparatus is provided which includes: means for distributing data to be transmitted in the form of bits via a first interleaver to a set of K frames; means for carrying out a puncturing or repetition method for data rate matching after interleaving; and means for varying a distance between punctured or repeated bits with regard to the sequence of the bits before the first interleaver, for puncturing or repeating the same number of bits in each frame, with the separation being defined by the following relationship: $q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) +1$, where $q := (\lfloor N_c/(|N_i-N_c|) \rfloor) \bmod K$, where $\lfloor\ \rfloor$ refers to rounding down and $|\ |$ refers to absolute value, and where $N_i :=$ the number of bits after rate matching, $N_c :=$ the number of bits before rate matching; and $\text{lcd}(q, K) :=$ highest common denominator of q and K.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a simplified flowchart with an interleaver before rate matching (prior art)~~;~~.

Figure 2 shows interleaving and puncturing patterns for puncturing of four bits per frame (prior art)~~;~~.

Figure 3 shows interleaving and shifted puncturing patterns for puncturing of four bits per frame (prior art)~~;~~.

Figure 4 shows interleaving and shifted puncturing patterns for puncturing with a puncturing ratio of 10% (prior art)~~;~~.

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Figure 5 shows a simplified illustration of transport channels (prior art)~~;~~.

Figure 6 shows interleaving and shifted puncturing patterns for puncturing of four bits per frame (prior art)~~;~~.

Figure 7 shows a block diagram of a mobile radio communications system (prior art)~~;~~.

Figure 8 shows a block diagram of a data communications arrangement, which forms a path between the mobile station and a base station in the communications network shown in Figure 7 (prior art)~~;~~.

Figure 9 shows puncturing patterns for shifted puncturing patterns for puncturing of two bits per frame (prior art)~~;~~.

Figure 10 shows a simplified illustration of the principle of puncturing which is optimized ~~with regard to the two said aims~~ in accordance with the present invention~~;~~.

Figure 11 shows a reference table~~;~~.

Figure 12 shows puncturing patterns for puncturing with a puncturing ratio of 20%~~;~~.

Figure 13 shows puncturing patterns for puncturing with a puncturing ratio of 1:8~~;~~.

Figure 14 shows puncturing patterns for puncturing with an odd number of bits to be punctured per frame.

DETAILED DESCRIPTION OF THE INVENTION

As explained above, the second aim ~~can admittedly not~~ cannot always be achieved adequately if every n-th bit were simply to be punctured after interleaving with respect to the original sequence before interleaving. However, the first aim would be achieved to an adequate extent.

In order to achieve both the abovementioned aims to a satisfactory extent, one embodiment ~~variant~~ of the present invention now provides, - in contrast to the uniform puncturing with respect to the original sequence before interleaving, - that the puncturing interval be varied at least once, and if necessary a number of times, in order to avoid some columns being preferred for puncturing, while others, on the

other hand, are not punctured at all. This is shown in Figure 10. Horizontal arrows (P6) with thin surrounding lines show a puncturing distance of 6, and the horizontal arrow (P5) with thick surrounding lines shows a puncturing distance of 5~~,~~ in order to avoid puncturing the first column twice. Once each column has been punctured once, the pattern (as shown by the vertical arrows) can be shifted six lines downward~~,~~ in order to define the next bits to be punctured. This obviously corresponds to puncturing of every sixth bit in each column, that is to say it corresponds to the use of a standard rate matching algorithm~~,~~ and to the shifting of puncturing patterns with respect to one another in different columns.

This method will now be described using formulae in the following text~~:~~.

Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_j is the index of the punctured/repeated bits, k the column or frame number after interleaving and K the number of interleaved columns or frames. The aim is to consider mainly the situation $N_i>N_c$, that is to say puncturing, but the formulae are also applicable to repetition.

In the above example, $N_i=20$, $N_c=16$, $m_1=4$, $m_2=9$, $m_3=14$, $m_4=19$, $k=1...7$, with k denoting the column or frame number after interleaving, and K=8. A comment is indicated by a prefix "--". The shifts V(k) = S(k) + T(k) * Q in the application of the puncturing or repetition pattern to the frame k can then be determined using the following method:

-- Calculation of the mean puncturing distance

$q:= (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$ -- where $\lfloor\ \rfloor$ ~~means round~~ refers to rounding down and $|\ |$ ~~means~~ refers to absolute value.

$Q:= (\lfloor N_c/(|N_i-N_c|)\rfloor)\ \mathrm{div}\ K$

if q even -- deal with as a special case:

then q = q - lcd(q, K)/K -- where lcd(q, K) ~~means~~ refers to the highest common denominator of q and K

-- It should be remembered that lcd ~~can~~ easily can be calculated by bit manipulation, since K is a power of 2.

-- For the same reason, calculations with q ~~ean~~ easily can be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S and T; S represents the shift in the line mod K, and T represents the shift magnitude div K;

S thus represents the shift in the line with respect to q (that is to say mod K) and T the magnitude of the shift with respect to Q (that is to say div K);

for i = 0 to K-1

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$ – where $\lceil\ \rceil$ ~~means round~~ referes to rounding up.

$T((R_K(\lceil i*q \rceil \bmod K)) = i$ -- $R_K(k)$ reverses the interleaver,

end for

In an actual implementation, these formulae can be implemented as shown in Figure 11, as a reference table. The table also includes the already described effect of the remapping of the column randomization achieved by $R_K(k)$. S also can ~~obviously also~~ be calculated from T, as a further implementation option.

e_{offset} can then be calculated as follows:

$$e_{offset}(k) = ((2*S) + 2*T\,Q + 1)*\,y + 1) \bmod 2Nc$$

Using $e_{offset}(k)$, e is then preloaded in the rate matching method for UMTS. This choice of e_{offset} obviously results in a shift in the puncturing patterns in the columns relative to one another by the amount S + T * Q.

The following text describes a simplified representation which simply results from the calculation of q and Q not being carried out separately for the remainder in the division by K and the multiple of K, but being combined for both components. In the same way, S and T cannot be calculated separately for q and Q, but likewise combined. The substitutions q+K*Q --> q and S+Q*T --> S result in the following equivalent representation of the method specified above, with the shift at V(k) in this case being given by: V(k) = S(k). Depending on the details of

the implementation, it may be better to carry out one calculation method or the other calculation method or ~~(~~further methods which are likewise equivalent to them~~)~~.

-- Calculation of the mean puncturing distance

$q := (\lfloor N_c/(|N_i - N_c|) \rfloor)$ -- where $\lfloor\ \rfloor$ ~~means round~~ refers to rounding down and $|\ |$ ~~means~~ refers to absolute value.

if q even -- deal with as a special case:

then q = q - lcd(q, K)/K -- where lcd(q, K) ~~means~~ refers to the highest common denominator of q and K

-- It should be noted that lcd ~~can~~ easily can be calculated by bit manipulation, since K is a power of 2.

-- For the same reason, calculations with q ~~can~~ easily can be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S(k) for the shift in the column k;

for i = 0 to K-1

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$ -- where $\lceil\ \rceil$ ~~means round~~ refers to rounding up.

-- $R_K(k)$ reverses the interleaver

end for

e_{offset} can then be calculated as follows:

$e_{offset}(k) = ((2*S) * y + 1) \bmod 2Nc$

Using $e_{offset}(k)$, e is then initialized in advance in the rate matching method.

If the puncturing rate is an odd-numbered fraction, that is to say 1:5 or 1:9, this method likewise produces a puncturing pattern which is optimum with regard to the two aims mentioned above and which would be used directly before the interleaving by the puncturing using the rate matching method. In other situations, adjacent bits are never punctured, but the distance between adjacent punctured bits may be greater than the others by up to lcd(q,K)+1. This method ~~can~~ also can be

applied in a corresponding manner to bit repetitions. Although the repetition of adjacent bits does not have such a severe influence on the performance of the error correction codes as is the case when puncturing adjacent bits, it is nevertheless advantageous to distribute repeated bits as uniformly as possible.

The fundamental objective of this method is to achieve a uniform distance between the punctured bits in the original sequence, but taking account of the constraint that the same number of bits must be punctured in the various frames. This is achieved ~~be~~ by reducing the puncturing distance by 1 in certain cases. The described method is optimum to the extent that the distance is never reduced by more than 1, and it is reduced only as often as is necessary. This results in the best-possible puncturing pattern subject to the constraints mentioned above.

The following example uses Figure 12 to show puncturing with a puncturing ratio of 1:5. The optimized algorithm obviously not only avoids the puncturing of adjacent bits, but punctured bits are also distributed with the same spacing in the original sequence. In fact, the same characteristics are achieved as if the puncturing were to be carried out directly after the coding and before the interleaving. In the specific case of 1:5 puncturing and, to put this in more general terms, whenever the puncturing rate can be written as a fraction 1:q, where q is an integer and q and K, the number of frames, do not have a common denominator, it can be said that an optimum puncturing pattern is produced despite the use of puncturing after the first interleaver. This puncturing pattern results in the puncturing of every qth bit, in the same way as an optimum puncturing pattern which had been carried out immediately after the coding and before the interleaving.

Puncturing with a puncturing ratio of 1:8 will now be analyzed with reference to Figure 13. Once again, the puncturing of adjacent bits is avoided. In this case, it is impossible to achieve uniformly spaced puncturing, since all the bits in an individual frame would then be punctured, which is completely unacceptable with respect to the second aim. In this case, most of the distances between adjacent bits are 7 (only one less than with an optimum distribution). In this case, some distances are greater (every eighth).

If the number N_i of input bits can be divided by K, the rate matching may vary during the transmission time interval. The last frames then have one bit less than the first~~,~~ and, therefore, also have a somewhat lower puncturing rate. For this situation, one embodiment ~~variant~~ of the present invention provides for the puncturing patterns in the last lines not to be changed. Instead of this, the same puncturing algorithm is used as for the first columns, but without carrying out the last puncturing operation. It can be seen from Figure 14 as an example that 125 input bits are intended to be punctured in such a manner that 104 output bits remain, which are interleaved over eight frames. The last two columns have one input bit less than the first; all the columns have 13 bits, since the last puncturing operation in the last two columns is omitted.

With regard to the aims mentioned above, the method proposed here allows optimized puncturing patterns to be specified when the rate matching is carried out after the first interleaving. The method is simple, requires little computation power and need be carried out only once per frame, and not once per bit. The method is not restricted to radio transmission systems.

Indeed, although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

~~Abstract~~

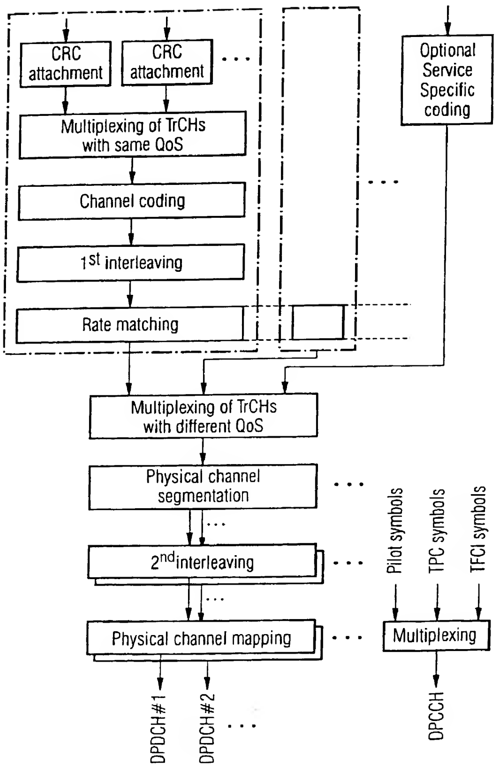
ABSTRACT

~~Method and apparatus for transmitting data frames, and a method and apparatus for data rate matching~~

A method and apparatus for data rate matching, wherein elements ~~Elements~~ to be transmitted are distributed over a number of radio frames ~~by means of~~ via an interleaver and are punctured or repeated, with the puncturing or repetition being carried out in such a manner that, when it is related to the original arrangement of the element before interleaving, the pattern avoids puncturing or repetition of adjacent elements, or of elements which are not far apart from one another.

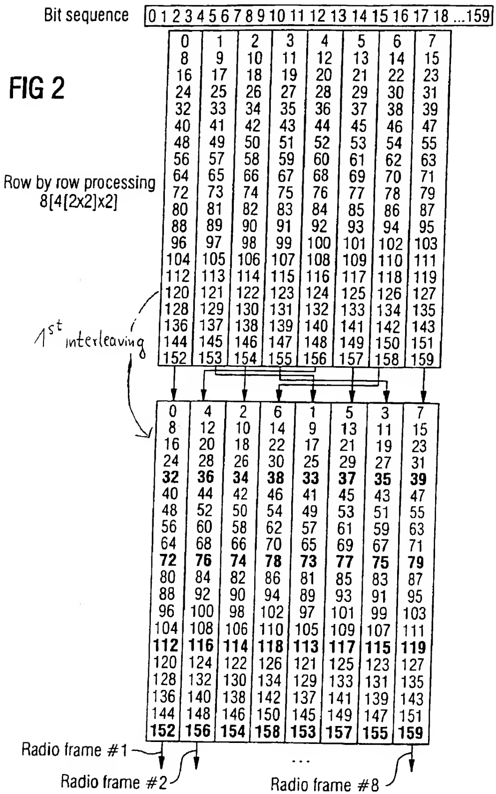
~~Figure 10~~

FIG 1



CRC attachment
CRC attachment
Optional Service Specific coding
Multiplexing of TrCHs with same QoS
Channel coding
1st interleaving
Rate matching
Multiplexing of TrCHs with different QoS
Physical channel segmentation
2nd interleaving
Physical channel mapping
Pilot symbols
TPC symbols
TFCI symbols
Multiplexing
DPDCH #1
DPDCH #2
DPCCH

FIG 2



0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151
152	153	154	155	156	157	158	159

0	4	2	6	1	5	3	7
8	12	10	14	9	13	11	15
16	20	18	22	17	21	19	23
24	28	26	30	25	29	27	31
32	**36**	**34**	**38**	**33**	**37**	**35**	**39**
40	44	42	46	41	45	43	47
48	52	50	54	49	53	51	55
56	60	58	62	57	61	59	63
64	68	66	70	65	69	67	71
72	**76**	**74**	**78**	**73**	**77**	**75**	**79**
80	84	82	86	81	85	83	87
88	92	90	94	89	93	91	95
96	100	98	102	97	101	99	103
104	108	106	110	105	109	107	111
112	**116**	**114**	**118**	**113**	**117**	**115**	**119**
120	124	122	126	121	125	123	127
128	132	130	134	129	133	131	135
136	140	138	142	137	141	139	143
144	148	146	150	145	149	147	151
152	**156**	**154**	**158**	**153**	**157**	**155**	**159**

FIG 3

Bit sequence: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...159

Row by row processing
8[4[2x2]x2]

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	**41**	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151
152	153	154	155	156	157	158	159

0	**4**	2	6	1	5	**3**	7
8	12	**10**	14	9	13	11	**15**
16	20	18	**22**	17	21	19	23
24	28	26	30	**25**	29	27	31
32	36	34	38	33	**37**	35	39
40	**44**	42	46	41	45	**43**	47
48	52	**50**	54	49	53	51	**55**
56	60	58	**62**	57	61	59	63
64	68	66	70	**65**	69	67	71
72	76	74	78	73	**77**	75	79
80	**84**	82	86	81	85	**83**	87
88	92	**90**	94	89	93	91	**55**
96	100	98	**102**	97	101	99	103
104	108	106	110	**105**	109	107	111
112	116	114	118	113	**117**	115	119
120	**124**	122	126	121	125	**123**	127
128	132	**130**	134	129	133	131	**135**
136	140	138	**142**	137	141	139	143
144	148	146	150	**145**	149	147	151
152	156	154	158	153	**157**	155	159

Radio frame #1

Radio frame #2

...

Radio frame #8

FIG 4

Bit sequence 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...159

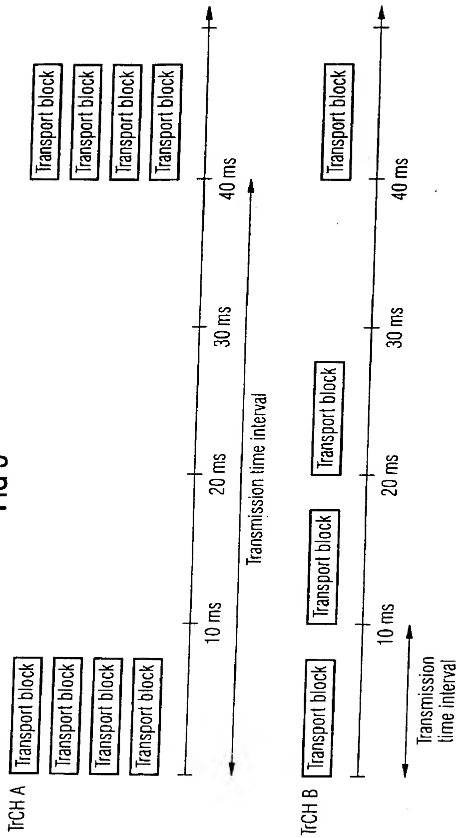
0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151
152	153	154	155	156	157	158	159

Row by row processing
8[4[2x2]x2]

0	4	2	6	1	5	3	7
8	**12**	10	14	9	13	**11**	15
16	20	18	22	17	21	19	23
24	28	**26**	30	25	29	27	**31**
32	36	34	38	33	37	35	39
40	44	42	**46**	41	45	43	47
48	52	50	54	49	53	51	55
56	60	58	62	**57**	61	59	63
64	68	66	70	65	69	67	71
72	76	74	78	73	**77**	75	79
80	84	82	86	81	85	83	87
88	**92**	90	94	89	93	**91**	55
96	100	98	102	97	101	99	103
104	108	**106**	110	105	109	107	**111**
112	116	114	118	113	117	115	119
120	124	122	**126**	121	125	123	127
128	132	130	134	129	133	131	135
136	140	138	142	**137**	141	139	143
144	148	146	150	145	149	147	151
152	156	154	158	153	**157**	155	159

Radio frame #1
Radio frame #2
...
Radio frame #8

FIG 5


TrCH A
Transport block
Transport block
Transport block
Transport block
10 ms
20 ms
30 ms
40 ms
Transmission time interval
Transport block
Transport block
Transport block
Transport block
TrCH B
Transport block
Transport block
Transport block
Transport block
10 ms
20 ms
30 ms
40 ms
Transmission time interval

6/12

Input bit sequence | 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...159 |

1st stage block Interleaving

FIG 6

Puncturing with simple shifting rule

0	1	2	3	4	**5**	6	7
8	**9**	10	11	12	13	**14**	15
16	17	**18**	19	20	21	22	**23**
24	25	26	**27**	28	29	30	31
32	33	34	35	**36**	37	38	39
40	41	42	43	44	**45**	46	47
48	**49**	50	51	52	53	**54**	55
56	57	**58**	59	60	61	62	**63**
64	65	66	**67**	68	69	70	71
72	73	74	75	**76**	77	78	79
80	81	82	83	84	**85**	86	87
88	**89**	90	91	92	93	**94**	95
96	97	**98**	99	100	101	102	**103**
104	105	106	**107**	108	109	110	111
112	113	114	115	**116**	117	118	119
120	121	122	123	124	**125**	126	127
128	**129**	130	131	132	133	**134**	135
136	137	**138**	139	140	141	142	**143**
144	145	146	**147**	148	149	150	151
152	153	154	155	**156**	157	158	159

Column randomizing

0	4	2	6	1	**5**	3	7
8	12	10	**14**	**9**	13	11	15
16	20	**18**	22	17	21	19	**23**
24	28	26	30	25	29	**27**	31
32	**36**	34	38	33	37	35	39
40	44	42	46	41	**45**	43	47
48	52	50	**54**	**49**	53	51	55
56	60	**58**	62	57	61	59	**63**
64	68	66	70	65	69	**67**	71
72	**76**	74	78	73	77	75	79
80	84	82	86	81	**85**	83	87
88	92	90	**94**	**89**	93	91	55
96	100	**98**	102	97	101	99	**103**
104	108	106	110	105	109	**107**	111
112	**116**	114	118	113	117	115	119
120	124	122	126	121	**125**	123	127
128	132	130	**134**	**129**	133	131	135
136	140	**138**	142	137	141	139	**143**
144	148	146	150	145	149	**147**	151
152	**156**	154	158	153	157	155	159

Frame #1 Frame #2 ... Frame #8

FIG 7

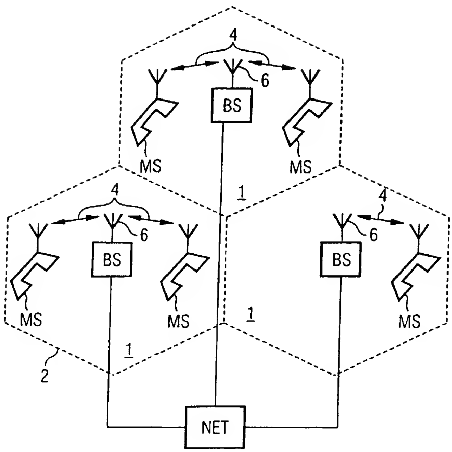


FIG 8

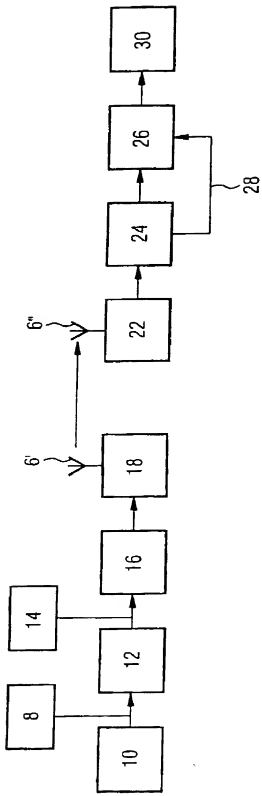


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FIG 9

0	1	2	3	**4**	5	6	7
8	9	10	**11**	12	**13**	14	15
16	17	18	19	20	21	**22**	23
24	25	26	27	28	29	30	**31**
32	33	34	35	36	37	38	39
40	**41**	42	43	44	45	46	47
48	49	**50**	51	52	53	54	55
56	57	58	**59**	60	61	62	63
64	65	66	67	**68**	69	70	71
72	73	74	75	76	**77**	78	79
80	81	82	83	84	85	**86**	87
88	89	90	91	92	93	94	**95**
96	97	98	99	100	101	102	103
104	**105**	106	107	108	109	110	111
112	113	**114**	115	116	117	118	119
120	121	122	**123**	124	125	126	127

FIG 10

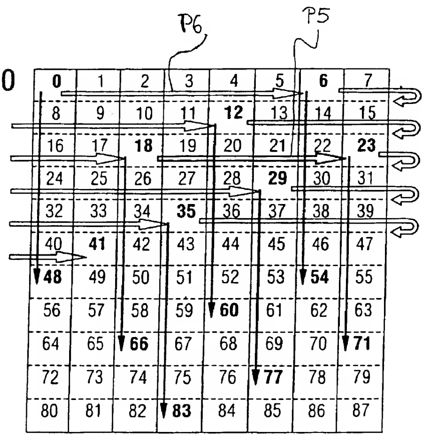


FIG 11

S;T	K	1	2		4				8							
	k	0	0	1	0	1	2	3	0	1	2	3	4	5	6	7
Q	1	0;0	0;0	0;1	0;0	0;2	0;1	0;3	0;0	0;4	0;2	0;6	0;1	0;5	0;3	0;7
	2		0;0	1;1	0;0	0;1	1;3	0;2	0;0	0;2	0;1	0;3	1;5	1;7	1;6	0;4
	3				0;0	1;2	2;3	0;1	0;0	1;4	2;6	0;2	1;3	2;7	0;1	1;5
	4				0;0	1;2	2;3	0;1	0;0	0;1	2;5	1;4	3;7	2;6	1;3	0;2
	5								0;0	3;4	2;2	4;6	4;5	1;1	5;7	2;3
	6								0;0	1;2	2;3	0;1	5;7	3;5	4;6	2;4
	7								0;0	3;4	5;6	1;2	6;7	2;3	4;5	0;1
	8								0;0	3;4	5;6	1;2	6;7	2;3	4;5	0;1

FIG 12

0	1	**2**	3	4	5	6	**7**
8	9	10	11	**12**	13	14	15
16	**17**	18	19	20	21	**22**	23
24	25	26	**27**	28	29	30	31
32	33	34	35	36	**37**	38	39
40	41	**42**	43	44	45	46	**47**
48	49	50	51	**52**	53	54	55
56	**57**	58	59	60	61	**62**	63
64	65	66	**67**	68	69	70	71
72	73	74	75	76	**77**	78	79
80	81	**82**	83	84	85	86	**87**
88	89	90	91	**92**	93	94	95
96	**97**	98	99	100	101	**102**	103
104	105	106	**107**	108	109	110	111
112	113	114	115	116	**117**	118	119
120	121	**122**	123	124	125	126	**127**
128	129	130	131	**132**	133	134	135
136	**137**	138	139	140	141	**142**	143
144	145	146	**147**	148	149	150	151
152	153	154	155	156	**157**	158	159

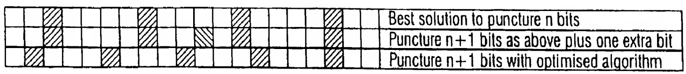
FIG 13

0	1	2	**3**	4	5	6	7
8	9	**10**	11	12	13	14	15
16	**17**	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	**39**
40	41	42	43	44	45	**46**	47
48	49	50	51	52	**53**	54	55
56	57	58	59	**60**	61	62	63
64	65	66	**67**	68	69	70	71
72	73	**74**	75	76	77	78	79
80	**81**	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	**103**
104	105	106	107	108	109	**110**	111
112	113	114	115	116	**117**	118	119
120	121	122	123	**124**	125	126	127

FIG 14

0	1	2	**3**	4	5	6	7
8	9	**10**	11	12	13	14	15
16	**17**	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	**39**
40	41	42	43	44	45	**46**	47
48	49	50	51	52	**53**	54	55
56	57	58	59	**60**	61	62	63
64	65	66	**67**	68	69	70	71
72	73	**74**	75	76	77	78	79
80	**81**	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	$\boxed{103}$
104	105	106	107	108	109	$\boxed{110}$	111
112	113	114	115	116	**117**	118	119
120	121	122	123	**124**	125		

FIG 15



Description

Method and apparatus for transmitting data frames, and a method and apparatus for data rate matching

The present invention relates to a method and an apparatus for transmitting data frames, and to a method and an apparatus for data rate matching, in particular using puncturing and/or repetition.

Digital communications systems are designed for transmitting data by representing the data in a form which makes it easier to transmit the data via a communication medium. For example, in the case of radio transmissions, the data is transmitted between transmitters and receivers in the communications system in the form of radio signals. In the case of broadband telecommunications networks, the data can be in the form of light, and can be transmitted, for example, via a fiber-optical network between transmitters and receivers in the system.

During data transmission, bits or symbols in the transmitted data may be corrupted, which means that these bits or symbols cannot be determined correctly in the receiver. For this reason, the data communications systems frequently contain means for ameliorating the corruption of the data which occurs during transmission. One of these means is to equip transmitters in the system with coders, which use an error control code to code the data before transmission. The error control code is designed such that it adds redundancy to the data, in a controlled manner. In the receiver, errors which occur during transmission can be corrected by decoding the error control code, as a result of which the original data is reproduced. The decoding is carried out using an error

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decoding algorithm, which corresponds to the error control code, which is known to the receiver.

Once the data has been decoded, it is often necessary, for data rate matching, to puncture or to repeat data bits or symbols from a block of coded data, before such data is transmitted. In this context, the term puncturing means a process of removing or deleting bits from a coded data block, with the effect that the punctured bit is not transmitted with this data block. Puncturing could be required, for example, because a multiple access method which is used for transmitting the data via the data-carrying media requires formatting of the data to form blocks of predetermined size, which size does not correspond to the size of the coded data frame.

In order to accommodate a coded data frame in a transport data block having a predetermined size, data bits are therefore either punctured from the coded data frame in order to reduce the size of the coded data block in a situation in which the coded data frame is larger than the size of the transport block, or bits in the coded data frame are repeated, in a situation in which the coded data frame is smaller than the predetermined size of the transport block.

In a situation in which the data frame is smaller than the transport data block, the data bits or symbols are repeated to the extent necessary to fill the rest of the transport data block.

Those skilled in the art are familiar with the fact that one effect of puncturing a coded data frame is that the probability of correct reproduction of the original data is reduced. Furthermore, the performance of known error control codes and the decoders of these error control codes is best when the errors which occur during the transmission of the data are caused by Gaussian noise, since this has

the effect that the errors are distributed independently throughout the transport data block. When a coded data frame is intended to be punctured, the positions in the coded data frame at which bits are punctured should be separated as far as possible from one another. To this extent, the puncturing positions should be distributed uniformly throughout the data frames. Since errors during transmission frequently occur in bursts, particularly in the case of radio communications systems which do not use interleaving, and since the repetitions are not intended to particularly improve the quality just in a certain region of the data frame but should be as uniform as possible, positions in a coded or uncoded data frame in which data bits are intended to be repeated should be arranged similarly so that they are uniformly separated from one another throughout the entire data frame.

Known methods for selecting positions of bits or symbols which are intended to be punctured or repeated in a coded data frame include the division of the number of bits or symbols in a frame by the number of bits or symbols which are intended to be punctured, and the selection of positions with integer values corresponding to the division. In a situation in which the number of bits to be punctured is not an integer division of the number of bits in the data frame, this does not, however, lead to uniform spacings between the punctured or repeated positions, thus resulting in the disadvantage that certain positions are closer than this integer number, or in some cases even alongside one another.

In order to describe the complex invention, the technical field of the invention and the problems that occur in this case will be briefly explained in the following text with reference to Figures 1 to 6 but, at least `partially, also result from the state of

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standardization for the 3rd mobile radio generation (UMTS (Universal Mobile Telecommunications System)) prior to the invention, which is specified in particular in the following

document: S1.12 v0.0.1, 3GPP FDD, Multiplexing, channel coding and interleaving description.

The interleaving in a transport multiplexing method is frequently carried out in two steps. The various solutions for carrying out the puncturing/repetition have specific consequences if the puncturing is carried out after the first interleaver, as is envisaged from the UMTS system. It can be assumed that the puncturing will be useful both in the uplink direction and in the downlink direction in order, for example, to avoid multicode. The current state of the specification for the UMTS system results in a potential problem, since, when using FS-MIL (FS-Multistage Interleaver) as the interleaver in the uplink direction multiplexing methods (Figure 1) in conjunction with the current rate matching algorithm proposed for UMTS, the performance could deteriorate.

As an example, let us consider a situation in which layer 2 results in a transport block with 160 bits on a transport channel with a transmission interval of 80 ms. This bit sequence can also be described as a data frame, or as a sequence of data frames. This means that, after the first interleaver, (first interleaving), the data is interleaved over eight frames (also often referred to as a radio frame in the following text) (see Figure 2). Let us now assume that four bits are intended to be punctured in each frame (radio frame) in order to produce a balance for the requirements for the quality of the service of this transport channel together with other channels. The result of the rate matching algorithm (which is intended for the UMTS system and is also, for simplicity, referred to as the rate matching algorithm in the following text) (where $e=N_c$) is that the bits 4, 9, 14 and 19 (index starts at 0, numbering based on the sequence of the bits after the first interleaving)

should be punctured in each frame (radio frame). In Figure 2, a punctured bit is illustrated in bold text. In consequence, eight

adjacent bits are punctured, and this, as explained above, is undesirable.

One obvious procedure to avoid this problem would be to shift the puncturing pattern in each frame. Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_1 is the index of the punctured/repeated bit, k is the frame number and K is the number of interleaved frames. Let us then consider the situation where $N_i>N_c$, that is to say puncturing. In the above example, $N_i=20$, $N_c=16$, $m_1=4$, $m_2=9$, $m_3=14$, $m_4=19$, $k=1...7$ and $K=8$. The shift could then be achieved using the following formula:

$m_{jshift} = (m_j + k*\lceil N_c/(N_c-N_c)/K \rceil) \bmod N_i$, *where* $\lceil\ \rceil$ *means round up.*

The same example as above would then give the result in Figure 3.

As can be seen from Figure 3, the puncturing of adjacent bits is admittedly avoided to a certain extent, but, however, there is a cyclic effect or edge effect, that is to say for example, the two bits 43 and 44 are punctured. If the puncturing ratio is low, the probability of puncturing adjacent bits decreases. Figure 4 shows an example with 10% puncturing. As can be seen from Figure 4, some adjacent bits are still punctured. It is thus possible for a decrease in performance to occur.

If the first interleaver is optimized and the second interleaver is kept simple, then the puncturing no longer requires the described rate matching algorithm. An optimized first interleaver should reorder the bits such that adjacent bits are separated. The puncturing can accordingly be carried out simply by removing successive bits after the interleaving process.

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However, there are two options. Let us consider the scenario illustrated in Figure 5.

The four blocks on TrCH A are interleaved together, and the rate matching is then carried out. When puncturing is used, successive bits are removed in each frame. It is therefore highly improbable that any punctured bits would be adjacent in a frame after the coding process. However, there is no guarantee that punctured bits would not be adjacent *in different frames* after the coding process. In consequence, a reduction in performance could occur when using this approach.

One alternative is to puncture successive bits only occasionally in individual transmission time intervals. The disadvantage of this approach is that bits on TrCH A are repeated at a time of 30 ms, since there is no data on TrCH B. It would probably have been better to reduce the extent of puncturing instead of puncturing a number of further bits. This problem has already been mentioned and was one of the reasons for combining static and dynamic rate matching. However, combined rate matching would also result in further advantages if this approach were to be used. Non-real-time transport blocks (NRT transport blocks) can still be transmitted, provided modifications are carried out to the original NRT concept. In the original proposal, it was possible to increase the puncturing and in this way to create space for the NRT block - although this would not be feasible with this new approach. The restriction in the above example was that the NRT block or the NRT blocks had to be shorter than, or precisely the same length as, the transport blocks in TrCH B. In situations in which repetition is used, the number of repeated bits may, however, naturally be reduced, in order to create space for the NRT blocks.

The problem for puncturing when FS-MIL is used in the uplink path multiplexing method has been mentioned. This problem occurs when

rate matching is carried out after the first interleaving.

When the current rate matching algorithm is used for an output from the first interleaver (intermediate frame FS-MIL), the number of adjacent bits in the specific line are punctured as shown in Figure 2. In order to avoid this, the shifting of the puncturing patterns is then introduced, in Figure 3. However, some adjacent bits are still punctured as a result of a cyclic effect or edge effect, resulting in certain deteriorations in performance.

The following modification for rate matching at that particular time could be effective to solve the above problem; that is to say puncturing using a simple shift rule prior to column randomization of the intermediate frame FS-MIL (the expression "line-by-line processing" has been changed to "line-by-line randomization" in order to make it easier to understand the major characteristics of the processing blocks).

Figure 6 shows an example of puncturing patterns when this modification is carried out for the same bit sequence example as before. The rate matching with a shift is carried out immediately after the block interleaving in the first stage. No puncturing of adjacent bits can now be seen in this figure. This puncturing should thus not result in any reduction in performance.

In fact, there is no need to carry out the above rate matching before the column randomization. The equivalent rate matching could be carried out after the column randomization by taking account of the column randomization rules, and this could easily be achieved just by replacing the initial offset value of the puncturing by a simple formula. The details of the

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modified rate matching algorithm are shown in List 1. This list introduces e_{offset}, in order to set the initial offset in each frame for uplink path

rate matching. The offset is not calculated on the basis of the column number after column randomization, but before column randomization, and this can be calculated using the inverse column interchanging rule. Furthermore, e_{offset} is not used just for puncturing, but also for repetition. Repetition bits could thus also be positioned more uniformly.

The interleaving in the transport multiplexing method is carried out in two steps. As explained in the above sections, consequences of the various solutions have specific consequences on the uplink path.

The following text shows that the previously proposed solutions, that is to say the proposed puncturing pattern, is still not always optimum in all situations. Against this background, the invention is based on the object of reducing these disadvantages of the prior art.

This object is achieved by the features of the independent claims. Developments of the invention can be found in the dependent claims.

Embodiments of the present invention will now be described just by way of example with reference to the attached drawings, in which:

Figures 1 to 6 show the prior art;

Figure 7 shows a block diagram of a mobile radio communications system;

Figure 8 shows a block diagram of a data communications apparatus, which forms a path between the mobile station and a base station in the communications network shown in Figure 1;

Figure 9 shows *first interleaving of 80 ms and 1:8 puncturing with an improved algorithm*

Figure 10 shows *the principle of optimized puncturing*

Figure 11 shows a reference table

Figure 12 shows *first interleaving of 80 ms and 1:5 puncturing*

Figure 13 shows *1:8 puncturing using the proposed algorithm*

Figure 14 shows *an odd number of bits per frame*

Figure 15 shows puncturing patterns

An exemplary embodiment of the present invention will be described in the context of a mobile radio communications system. Mobile radio communications systems are equipped with multiple access systems which operate, for example, on the basis of time division multiple access (TDMA) as is used, for example, in the global mobile radio system (GSM), a mobile radio communications standard which is standardized by the European Telecommunications Standard Institution. As an alternative, the mobile radio communications system could be equipped with a multiple access system operating using code division multiple access (CDMA), such as the UMTS system proposed for the third-generation universal mobile telecommunications system. However, as can be seen, any desired data communications system could be used to represent an exemplary embodiment of the present invention, such as a local data network or a broadband telecommunications network operating using the asynchronous transmission mode. These examples of data communications systems are characterized in particular in that data is transmitted as frames, packets or blocks. In the case of a mobile radio communications system, the data is transmitted within radio signals which carry data and represent a predetermined amount of data. Figure 7 shows one example of such a mobile radio communications system.

Figure 7 shows three base stations BS which exchange radio signals with mobile stations MS in a radio coverage area which is formed by cells 1, which are defined by dashed lines 2. The base

stations BS are coupled to a network relay system NET. The mobile stations MS and the base stations BS exchange data by using radio signals, which are annotated 4, to transmit between antennas 6, which are coupled to the mobile stations MS and to the base stations BS. The data is transmitted between the mobile stations MS and the base stations BS using a data communications apparatus, in which the data is transformed into radio signals 4, which are transmitted to the receiving antenna 6, which identifies the radio signals. The data is reproduced from the radio signals by the receiver.

Figure 8 shows an example of a data communications apparatus which forms a radio communication path between one of the mobile stations MS and one of the base stations BS, with parts which also appear in Figure 7 having identical numerical designations. In Figure 8, a data source 10 produces data frames 8 at a rate which is governed by the type of data produced by the source. The data frames 8 produced by the source 10 are supplied to a rate converter 12, which converts the data frames 8 to form transport data blocks 14. The transport data blocks 14 are designed such that they are of essentially the same size, with a predetermined size and an amount of data which can be carried by frames in data-carrying radio signals, via which data is transmitted by a radio interface which is formed from a pair comprising a transmitter 18 and a receiver 22.

The data transport block 14 is supplied to a radio access processor 16, which controls the sequence of transmission of the transport data block 14 via the radio access interface. The transport data block 14 is supplied at an appropriate time by the radio access processor 16 to a transmitter 18, which converts the transport data block to the frame of data-carrying radio signals, which are transmitted in a

time interval which is allocated to that transmitter, in order to transmit the radio signals. In the receiver 22, a receiver antenna 6'' identifies the radio signals and carries out downward conversion and reproduction of the data frame, and this is supplied to a radio access sequence control reversing apparatus 24. The radio access sequence control reversing apparatus 24 supplies the received data transport block to a frame conversion reversing apparatus 26 which is controlled by the multiple access sequence control reversing apparatus 24, and is supplied via a conductor 28. The rate conversion reversing apparatus 26 then supplies a representation of the reproduced data frame 8 to a destination or sink for the data frame 8, which is represented by the block 30.

The rate converter 12 and the rate conversion reversing apparatus 26 are designed such that, as far as possible, they utilize the data-carrying capacity available in the transport data block 14 optimally. According to the exemplary embodiment of the present invention, this is done by means of the rate matching converter 12, which is used to code the data frame and then puncture or repeat data bits or symbols which are selected from the coded data frame, with the effect of producing a transport data block which fits into the data blocks 14. The rate converter 12 has a coder and a puncturer. The data frame 8 which is supplied to the coder is coded, in order to produce a coded data frame which is supplied to the puncturer. The coded data frame is then punctured by the puncturer, in order to produce the data transport block 14.

It is assumed that the puncturing can be carried out both in the uplink direction and in the downlink direction. When the ETSI and ARIB specifications were joined together to form the UMTS specification, ARIB made the assumption that no puncturing is carried out

in the uplink direction. It is assumed that the puncturing will also

be useful in the uplink direction, in order, for example, to avoid multicode. There is then a potential problem since the performance could deteriorate when using FS-MIL in the uplink path multiplexing method in conjunction with the present rate matching algorithm. This has been shown with reference to Figure 2 by an example of an analysis of a situation in which layer 2 supplies a transport block with 160 bits on a transport channel with a transmission interval of 80 ms, subject to the precondition that four bits should be punctured in each frame. This means that eight adjacent bits are punctured, which is obviously undesirable.

The proposal as shown in Figure 3 is to shift the puncturing pattern in each frame. This is then also equivalent to the use of puncturing before column mixing, if it is actually carried out before the intermediate frame interleaving. In fact, in contrast to the example in Figure 2, no adjacent punctured bits are produced in this example.

However, in a method as shown in Figure 2, there are always still situations in which adjacent bits are punctured, depending on the puncturing rate. Figure 9 shows, for example, the situation $N_i=16$, $N_c=14$, $m_1=4$, $m_2=14$, $k=1...7$ and $K=8$. For the sake of simplicity, Figure 9 and Figure 10 show only the area before interleaving, in which, however, those bit positions which are punctured after interleaving are illustrated by marking them in bold print. As can be seen, the adjacent bits 31-32 and 95-96 are punctured, which is obviously undesirable.

A first aim of a good puncturing algorithm is to distribute punctured bits as uniformly as possible over the bit positions in their original sequence. This was also the critical principle which was used for the definition of the puncturing algorithm for UMTS, as is

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described, for example, in the abovementioned Specification

S1.12. This is best done by puncturing every n-th bit or, in some cases, every (n+first) bit if the puncturing rates are not integral.

A second aim is to puncture the various columns (in the following text, frames are also often referred to as columns) with equal frequency, and hence also to distribute the punctured bits uniformly over all the radio frames (frames), and also to achieve uniform puncturing in the various columns. The expressions puncturing or repetition of a column (for the frame) also mean the puncturing or repetition of an element in the column (in the frame).

However, if the principle explained above is also applied to puncturing after interleaving, then the second aim can no longer be adequately achieved. Let us consider, for example, 80-ms interleaving and a puncturing rate of 1:6. Puncturing every sixth bit would result in only the columns 0, 2, 4, 6, but not 1, 3, 5, 7 being punctured, which is, of course, impossible.

In order to achieve both aims, one embodiment variant of the invention provides for the puncturing interval to be changed at least once, and if necessary more than once, in order to avoid some columns being preferred for puncturing, while others, on the other hand, are not punctured at all. This is shown in Figure 10. Horizontal arrows (P6) with thin surrounding lines show a puncturing distance of 6, and the horizontal arrow (P5) with thick surrounding lines shows a puncturing distance of 5, in order to avoid puncturing the first column twice. Once each column has been punctured once, the pattern (as shown by the vertical arrows) can be shifted six lines downward, in order to define the next bits to be punctured. This obviously corresponds to the puncturing of every sixth bit in each column, that is

to say it corresponds to the use of a standard rate matching algorithm, and to the shifting of puncturing patterns with respect to one another in different columns.

This method will now be described using formulae in the following text:

Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_j is the index of the punctured/repeated bits, k is the frame number and K is the number of interleaved frames. The aim is to consider mainly the situation $N_i>N_c$, that is to say puncturing, but the formulae are also applicable to repetition. In the above example, $N_i=20$, $N_c=16$, $m_1=4$, $m_2=9$, $m_3=14$, $m_4=19$, k=1...7 and K=8. The shifting could then be achieved using the following formula:

-- Calculation of the mean puncturing distance

q:= $(\lfloor N_c/(|N_i-N_c|)\rfloor)$ *mod K* -- *where* $\lfloor\ \rfloor$ *means round down and* $|\ |$ *means absolute value.*

Q:= $(\lfloor N_c/(|N_i-N_c|)\rfloor)$ *div K*

if q even -- *deal with as a special case:*

then q = q - lcd(q, K)/K -- where lcd(q, K) means the highest common denominator of q and K

-- It should be remembered that lcd can easily be calculated by bit manipulation, since K is a power of 2.

-- For the same reason, calculations with q can easily be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S and T; S represents the shift in the line mod K, and T represents the shift magnitude div K;

S thus represents the shift in the line with respect to q (that is to say mod K) and T the magnitude of the shift with respect to Q (that is to say div K);

for i = 0 to $K-1$

$S(R_K\ (\lceil i*q\rceil \bmod K)) = (\lceil i*q\rceil \text{ div } K)$ -- *where* $\lceil\ \rceil$ *means round up.*

$T((R_K(\lceil i*q \rceil \bmod K)) = i$ -- $R_K(k)$

reverses the interleaver,

end for

In an actual implementation, these formulae can be implemented as shown in Figure 11, as a reference table. The table also includes the effect of remapping the column randomization achieved by $R_K(k)$. S can obviously also be calculated from T, as a further implementation option.

e_{offset} can then be calculated as follows:

e_{offset} (k) = ((2*S) + 2*T Q +1)* y + 1) mod $2Nc$

Using e_{offset} (k), e is then preloaded in the rate matching method for UMTS. This choice of e_{offset} obviously results in a shift in the puncturing patterns in the columns relative to one another by the amount S + T * Q.

The following text describes a simplified representation which simply results from the calculation of q and Q not being carried out separately for the remainder in the division by K and the multiple of K, but being combined for both components. In the same way, S and T cannot be calculated separately for q and Q, but likewise combined. The substitutions q+K*Q --> q and S+Q*T --> S result in the following equivalent representation. Depending on the details of the implementation, it may be better to carry out one calculation method or the other calculation method (or further methods which are likewise equivalent to them).

-- Calculation of the mean puncturing distance

q:= $(\lfloor N_c/(|N_i-N_c|)\rfloor)$ -- *where* $\lfloor\ \rfloor$ *means round down and* $|\ |$ *means absolute value.*

if q even -- *deal with as a special case:*

then q = q - lcd(q, K)/K -- where lcd(q, K) means the highest common denominator of q and K

-- It should be noted that lcd can easily be calculated by bit manipulation, since K is a power of 2.

-- For the same reason, calculations with q can easily be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S(k) for the shift in the column k;

for *i* = *0* to *K-1*
*S(R_K (⌈i*q⌉ mod K)) = (⌈i*q⌉ div K) -- where ⌈ ⌉ means round up.*
-- *R_K(k) reverses the interleaver*
end for

e_{offset} can then be calculated as follows:
e_{offset} (k) = ((2*S) * y + 1) mod *2Nc*
Using e_{offset} (k), e is then initialized in advance in the rate matching method.

If the puncturing rate is an odd-numbered fraction, that is to say 1:5 or 1:9, this method produces the same perfect puncturing pattern as that which would be used directly before interleaving by puncturing using the rate matching method. In other situations, adjacent bits are never punctured, but the distance between punctured bits may be greater than the others by up to lcd(q,K)+1. This method can also be applied in a corresponding manner to bit repetitions. Although the repetition of adjacent bits does not have such a severe influence on the performance of the error correction codes as is the case when puncturing adjacent bits, it is nevertheless advantageous to distribute repeated bits as uniformly as possible.

The fundamental objective of this method is to achieve a uniform distance between the punctured bits in the original sequence, but taking account of the constraint that the same number of bits must be punctured in the various frames. This is achieved be reducing the puncturing distance by 1 in certain cases. The described method is optimum to the extent that the distance is never reduced by more than 1, and it is reduced only as often as is necessary. This results in the

best-possible puncturing pattern subject to the constraints mentioned above.

The following example shows the use of the first set of parameters, that is to say puncturing with 1:5 (Figure 12). The optimized algorithm obviously not only avoids the puncturing of adjacent bits, but punctured bits are also distributed with the same spacing in the original sequence. In fact, the same characteristics are achieved as if the puncturing were to be carried out directly after the coding and before the interleaving.

We will now investigate the next case, that is to say puncturing with 1:8 (Figure 13). Once again, the puncturing of adjacent bits is avoided. In this case, it is impossible to achieve uniformly spaced puncturing, since all the bits in an individual frame would then be punctured, which is completely unacceptable. In this case, most of the distances between adjacent bits are 7 (only one less than with an optimum distribution). In this case, some distances are greater (every eighth).

In two situations, the rate matching may vary during the transmission time interval:

a) The number Ni of input bits is not divisible by K. The last frames then have one bit less than the first, and therefore also have a somewhat lower puncturing rate. It should be remembered that it is not clear whether this situation will be permissible or whether it is expected that the coding will supply a suitable number.
b) Owing to fluctuations in other services which are multiplexed onto the same link, the puncturing may be weakened in later frames.

In these situations, the balanced puncturing method could still suffer from disadvantages. Owing to the

unpredictable nature of case b), it appears to be improbable that it will be possible to find any method whatsoever which could lead to a virtually perfect

puncturing pattern, and in this situation it is therefore necessary to accept a certain unpredictable behavior in each case. However, in case a), it is proposed that the puncturing pattern should not be varied in the last lines. Instead of this, it is proposed that the same puncturing algorithm be used as for the first columns, but simply with the last puncturing being omitted. Let us consider, as an example, a situation in which 125 input bits are intended to be punctured, in order to obtain 104 output bits which are interleaved over eight frames. The puncturing pattern would then appear as shown in Figure 14. The last columns have one input bit less than the first while, due to the omission of the last puncturing, the columns all have 13 bits.

Furthermore, it is proposed as an alternative that an optimized first interleaver be used, with a simple second interleaver and a simple puncturing method being used. This is based on the expectation that an optimized interleaver will distribute bits such that the puncturing of blocks of bits after the interleaving will distribute these punctured bits uniformly before interleaving. However, experience with puncturing after a simple first interleaver has shown that this is not an easy task. Since the individual interleaver cannot be optimized for all puncturing rates, it is virtually impossible to achieve good characteristics: the reason for this is as follows: the puncturing patterns (Figure 15) for n+1 bits must be identical to the puncturing pattern for n bits, although an additional bit can be chosen for puncturing. If the puncturing pattern is good for n bits (see the first line in the table in Figure 15), then it is impossible to achieve an optimum distribution of n+1 bits (last line) irrespective of which specific bit is additionally punctured in order to obtain n+1 bits (second line).

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Furthermore, such an interleaver would need to be a compromise between good puncturing characteristics for

block puncturing and, at the same time, good general interleaving characteristics (for example in order to achieve good transmission characteristics for transmission via fading channels). Since no such method and no such interleaver are known, the method described in the present application is particularly advantageous, in which puncturing is carried out after a simple first interleaver with a subsequent second interleaver with optimized interleaving characteristics.

Virtually optimum puncturing patterns are thus possible, if the rate matching is carried out after the first interleaving. The method is simple, requires little computation power and need be carried out only once per frame, and not once per bit.

The method described above is not restricted to radio transmission systems.

Patent Claims

1. A method for data rate matching in which data to be transmitted is distributed in the form of bits by means of a first interleaver to a set comprising a number of frames, in which a puncturing and repetition method is carried out for data rate matching after the interleaving, in that the same number of bits are punctured and/or repeated in each frame, and the punctured and/or repeated bits are separated from one another as uniformly as possible with regard to the sequence of the bits before the first interleaver.

2. The method as claimed in claim 1, in which the puncturing and repetition rate is an integer fraction (1/p), where p and the number of radio frames K have no common denominator, and, in which the puncturing and repetition process is carried out in such a manner that the punctured and repeated bits are separated equally from one another with regard to the sequence of the bits before the first interleaver.

3. The method as claimed in one of claims 1 or 2, in which a puncturing and repetition process is carried out in such a manner that the puncturing and repetition pattern used within a frame is also used, shifted, within further frames in the set of frames.

4. The method as claimed in claim 3, in which the puncturing and repetition rate is NOT an integer fraction (1/p) or p, and the number of frames K have no common denominator, and the

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shifting of the use of the puncturing and repetition pattern is carried out to radio frames corresponding to the relative shift of the next-higher puncturing or

repetition rate which is an integer fraction (1/p), where p and the number of frames K have no common denominator.

5. The method as claimed in claim 3, in which the shift S(k) + T(k) * Q in the use of the puncturing and repetition pattern to the frame k can be produced by means of the following method:

-- Calculation of the mean puncturing distance

q:= $(\lfloor N_c/(|N_i-N_c|)\rfloor)$ *mod K -- where* $\lfloor\ \rfloor$ *means round down and* $|\ |$ *means absolute value.*

Q:= $(\lfloor N_c/(|N_i-N_c|)\rfloor)$ *div K*

if q even -- *deal with as a special case:*

then q = q - lcd(q, K)/K -- where lcd(q, K) means the highest common denominator of q and K

endif

for *i = 0* to *K-1*

*S(R_K ($\lceil$i*q$\rceil$ mod K)) = ($\lceil$i*q$\rceil$ div K) -- where* $\lceil\ \rceil$ *means round up.*

*T((R_K ($\lceil$i*q$\rceil$ mod K)) = i -- R_K(k) reverses the interleaver,*

end for.

6. The method as claimed in claim 3, in which the shift S(k) of the use of the puncturing and repetition pattern to the frame k can be produced by means of the following method:

-- Calculation of the mean puncturing distance

q:= $(\lfloor N_c/(|N_i-N_c|)\rfloor)$ *-- where* $\lfloor\ \rfloor$ *means round down and* $|\ |$ *means absolute value.*

if q even -- *deal with as a special case:*

then q = q - lcd(q, K)/K -- where lcd(q, K) means the highest common denominator of q and K

endif

- Calculate S(k) for the shift in the column k;

for *i = 0* to *K-1*

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$ -- *where* $\lceil\ \rceil$ *means round up.*

-- $R_K(k)$ *reverses the interleaver*

end for.

7. The method as claimed in one of the preceding claims, in which bits which are to be punctured or to be repeated are produced by means of a method which includes the following steps:

a) Determine the integer component q of the mean puncturing distance using $q := (\lfloor N_c / (|N_i - N_c|) \rfloor)$ -- *where* $\lfloor\ \rfloor$ *means round down and* $|\ |$ *means absolute value,* N_i *and* N_c *are the number of elements after and before rate matching;*

b) Select a bit to be punctured or to be repeated in a first column;

c) Select the next bit to be punctured or to be repeated in the next column, starting from the last bit to be punctured or to be repeated in the previous column by in each case selecting the next bit at the distance q, with respect to the original sequence, starting with this last bit to be punctured or to be repeated, providing this does not lead to a column being punctured or repeated twice, or otherwise by selecting a bit whose distance is other than q;

d) repetition of step c) until all columns have been punctured or repeated once.

8. The method as claimed in claim 7, in which the distance q-1 or q+1 is selected for determining the next bit, where the use of the distance q would lead to a column being punctured or repeated twice.

9. The method as claimed in one of claims 7 or 8, in which a first column is punctured or repeated using a standard rate matching algorithm, and, in order to select further bits to be punctured or to be repeated, the puncturing pattern in this column is shifted in a corresponding way to the position of the bit determined in step b of claim 7, within the respective column, relative to the position of the bit determined in step a of claim 7 in the column selected first of all.

10. A data rate matching apparatus, in particular a processor device,
having means for carrying out a method as claimed in one of claims 1 to 9.

11. A method for transmitting data frames, by which means the transmitted elements are distributed between one or more frames by using an interleaver, and with the elements being punctured or repeated, and with the puncturing or repetition being carried out such that, when it is related to the original arrangement of the elements before interleaving, the pattern avoids puncturing/ repetition of adjacent elements or of elements which are not far apart from one another.

12. A method for transmitting data frames, in which the transmitted elements are distributed between one or more frames by using an interleaver, and in which the elements are punctured or repeated, with the puncturing or repetition being carried out such that, when it is related to the original arrangement of the elements before interleaving, the pattern has uniform spacings, or approximately uniform spacings.

13. The method as claimed in claim 11 or 12, in which the elements to be punctured can be determined by first of all calculating q, the integer part of the mean puncturing distance,

$q := (\lfloor N_c/(|N_i - N_c|)\rfloor)$ -- *where* $\lfloor\ \rfloor$ *means round down and* $|\ |$ *means absolute value,* N_i *and* N_c *are the number of elements after and before rate matching,* then, starting from an element to be punctured in the first column, the subsequent elements to be punctured are selected in that the next element at the distance p, related to the original order, is in each case selected, starting with this first element, provided this does not lead to a column being punctured twice, otherwise using a different distance, and this method is continued until all the columns have been punctured once, and only once.

14. The method as claimed in claim 13 in which, if the use of the distance q would lead to a column being punctured twice, the distance q-1 or q+1 is selected for determining the next element.

15. The method as claimed in claim 13, in which the elements to be punctured can be determined by puncturing the first column using a standard rate matching algorithm, and using the method in claim 18b, starting from the first punctured element of the first column, in order to determine one element in each of the other columns, and the further elements in the other columns being determined by shifting the puncturing pattern of the first column such that it corresponds to the relative position of the element determined in claim 13, within the respective column.

16. A method for transmitting data frames, in which the transmitted elements are distributed between one or more frames by using an interleaver, and in which the elements are punctured or repeated, with the puncturing or repetition pattern that occurs in the frames being shifted with respect to the

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first frame such that, when it is related to the original arrangement of the elements before interleaving, the resultant puncturing or repetition pattern

has uniform spacings, or approximately uniform spacings.

17. The method for transmitting data frames as claimed in one of claims 11 to 16, in which the puncturing/repetition rate is an integer fraction (1/p), where p and the number of frames K have no common denominator, as a result of which the patterns which occur in the frames are shifted with respect to the first frame such that, when it is related to the original arrangement of the elements before interleaving, the resultant puncturing or repetition pattern has uniform spacings.

18. The method for transmitting data frames as claimed in one of claims 11 to 17, in which the puncturing/repetition rate is NOT an integer fraction (1/p) or p and the number of frames K have no common denominator, as a result of which the patterns which occur in the frames are shifted with respect to the first frame by using the relative shifts which would be used for the next-higher puncturing rate which satisfies the precondition for the preceding claim.

19. The method for transmitting data frames as claimed in one of claims 11 to 18, in which the number of elements for puncturing/repetition is NOT identical in all the frames, as a result of which the same patterns as in the preceding claims are used, but some of the puncturing/repetition is not carried out.

20. The method for transmitting data frames as claimed in one of claims 11 to 19, in which the number of elements for puncturing/repetition is NOT identical in all the frames, as a result of which

the same patterns as in the preceding claims are used, but the puncturing/repetition is not carried out for the first or last elements.

21. The method for transmitting data frames as claimed in one of claims 11 to 20, with puncturing being carried out.

22. The method for transmitting data frames as claimed in one of claims 11 to 20, with repetition being carried out.

23. The method for transmitting data frames as claimed in one of claims 11 to 22, with the elements being binary digits.

24. The method for transmitting data frames as claimed in one of claims 11 to 23, with the frames having a duration of 10 ms, and the interleaving being carried out over a power of two frames.

25. The method for transmitting data frames as claimed in one of claims 11 to 24, with the frames being transmitted using a CDMA transmission system.

26. A data communications apparatus, which is used for transmitting data frames, in which the apparatus comprises means for transmitting data frames as claimed in one of claims 11 to 25.

09/937035

Abstract

Method and apparatus for transmitting data frames, and a method and apparatus for data rate matching

Elements to be transmitted are distributed over a number of radio frames by means of an interleaver and are punctured or repeated, with the puncturing or repetition being carried out in such a manner that, when it is related to the original arrangement of the element before interleaving, the pattern avoids puncturing or repetition of adjacent elements, or of elements which are not far apart from one another.

Figure 10

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Description

Data transmission with interleaving and subsequent rate matching by puncturing or repetition

The present invention relates to a method and an apparatus for data transmission with interleaving and subsequent rate matching owing to puncturing or repetition.

Digital communications systems are designed for transmitting data by representing the data in a form which makes it easier to transmit the data via a communication medium. For example, in the case of radio transmissions, the data is transmitted between transmitters and receivers in the communications system in the form of radio signals. In the case of broadband telecommunications networks, the data can be in the form of light, and can be transmitted, for example, via a fiber-optical network between transmitters and receivers in the system.

During data transmission, bits or symbols in the transmitted data may be corrupted, which means that these bits or symbols cannot be determined correctly in the receiver. For this reason, the data communications systems frequently contain means for ameliorating the corruption of the data which occurs during transmission. One of these means is to equip transmitters in the system with coders, which use an error control code to code the data before transmission. The error control code is designed such that it adds redundancy to the data, in a controlled manner. In the receiver, errors which occur during transmission can be corrected by decoding the error control code, as a result of which the original data is reproduced. The decoding is carried out using an error

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decoding algorithm, which corresponds to the error control code, which is known to the receiver.

Once the data has been decoded, it is often necessary, for data rate matching, to puncture or to repeat data bits or symbols from a block of coded data, before such data is transmitted. In this context, the term puncturing means a process of removing or deleting bits from a coded data block, with the effect that the punctured bit is not transmitted with this data block. Puncturing could be required, for example, because a multiple access method which is used for transmitting the data via the data-carrying media requires formatting of the data to form blocks of predetermined size, which size does not correspond to the size of the coded data frame.

In order to accommodate the coded data frame in a transport data block having a predetermined size, data bits are therefore either punctured from the coded data frame in order to reduce the size of the coded data block in a situation in which the coded data frame is larger than the size of the transport data block, or bits in the coded data frame are repeated, in a situation in which the coded data frame is smaller than the predetermined size of the transport data block. This will be explained in more detail in the following text using a mobile radio communications system by way of example:

Mobile radio communications systems are equipped with multiple access systems which operate, for example, on the basis of time division multiple access (TDMA) as is used, for example, in the global mobile radio system (GSM), a mobile radio communications standard which is standardized by the European Telecommunications Standard Institution. As an alternative, the mobile radio communications system could be equipped with a multiple access system operating using code division multiple access (CDMA), such as the UMTS system

proposed for the third-generation universal mobile telecommunications system.

However, as can be seen, any desired data communications system could be used to represent an exemplary embodiment of the present invention, such as a local data network or a broadband telecommunications network operating using the asynchronous transmission mode. These examples of data communications systems are characterized in particular in that data is transmitted as frames, packets or blocks. In the case of a mobile radio communications system, the data is transmitted within radio signals which carry data and represent a predetermined amount of data. Figure 7 shows one example of such a mobile radio communications system.

Figure 7 shows three base stations BS which exchange radio signals with mobile stations MS in a radio coverage area which is formed by cells 1, which are defined by dashed lines 2. The base stations BS are coupled to a network relay system NET. The mobile stations MS and the base stations BS exchange data by using radio signals, in that they transmit radio signals 4 between antennas 6, which are coupled to the mobile stations MS and to the base stations BS. The data is transmitted between the mobile stations MS and the base stations BS using a data communications apparatus, in which the data is transformed into radio signals 4, which are transmitted to the receiving antenna 6, which identifies the radio signals. The data is reproduced from the radio signals by the receiver. The invention can in this case be used both in the uplink direction (MS -> BS) and in the downlink direction (BS -> MS).

Figure 8 shows an example of a data communications apparatus which forms a radio communication path between one of the mobile stations MS and one of the base stations BS, with parts which also appear in Figure 7 having identical numerical designations. In

Figure 8, a data source 10 produces data frames 8 at a rate which is governed by

the type of data produced by the source. The data frames 8 produced by the source 10 are supplied to a rate converter 12, which converts the data frames 8 to form transport data blocks 14. The transport data blocks 14 are designed such that they are of essentially the same size, with a predetermined size and an amount of data which can be carried by frames in data-carrying radio signals, via which data is transmitted by a radio interface which is formed from a pair comprising a transmitter 18 and a receiver 22.

The transport data block 14 is supplied to a radio access processor 16, which controls the sequence of transmission of the transport data block 14 via the radio access interface. The transport data block 14 is supplied at an appropriate time by the radio access processor 16 to a transmitter 18, which converts the transport data block to the frame of data-carrying radio signals, which are transmitted in a time interval which is allocated to that transmitter, in order to transmit the radio signals. In the receiver 22, a receiver antenna 6'' identifies the radio signals and carries out downward conversion and reproduction of the data frame, and this is supplied to a radio access sequence control reversing apparatus 24. The radio access sequence control reversing apparatus 24 supplies the received data transport block to a frame conversion reversing apparatus 26 which is controlled by the multiple access sequence control reversing apparatus 24, and is supplied via a conductor 28. The rate conversion reversing apparatus 26 then supplies a representation of the reproduced data frame 8 to a destination or sink for the data frame 8, which is represented by the block 30.

The rate converter 12 and the rate conversion reversing apparatus 26 are designed such that, as far as possible, they utilize the data-carrying capacity

available in the transport data block 14 optimally. According to an exemplary embodiment of the present invention, this is done by means of the rate matching converter 12, which is used to code the data frame and then puncture or repeat data bits or symbols which are selected from the coded data frame, with the effect of producing a transport data block which fits into the data blocks 14. The rate converter 12 has a coder and a puncturer. The data frame 8 which is supplied to the coder is coded, in order to produce a coded data frame which is supplied to the puncturer. The coded data frame is then punctured by the puncturer, in order to produce the transport data block 14. Depending on the embodiment variant, puncturing of frames can be used both in the uplink direction and in the downlink direction.

GB 2296165 A discloses a multiplex communications system, which has puncturing and interleaving.

Those skilled in the art are familiar with the fact that one effect of puncturing a coded data frame is that the probability of correct reproduction of the original data is reduced. Furthermore, the performance of known error control codes and the known decoders of these error control codes is best when the errors which occur during the transmission of the data are caused by Gaussian noise, since this has the effect that the errors are distributed independently throughout the transport data block. When a coded data frame is intended to be punctured, the positions in the coded data frame at which bits are punctured should be separated as far as possible from one another. To this extent, the puncturing positions should be distributed uniformly throughout the data frames. Since errors during transmission frequently occur in bursts, particularly in the case of radio communications

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systems which do not use interleaving, and since the repetitions of bits

are not intended to particularly improve the quality just in a certain region of the data frame but should be as uniform as possible, positions in a coded or uncoded data frame in which data bits are intended to be repeated should be arranged similarly so that they are uniformly separated from one another throughout the entire data frame.

Known methods for selecting positions of bits or symbols which are intended to be punctured in a coded data frame include the division of the number of bits or symbols in a frame by the number of bits or symbols which are intended to be punctured, and the selection of positions with integer values corresponding to the division. In a situation in which the number of bits to be punctured is not an integer division of the number of bits in the data frame, this does not, however, lead to uniform spacings between the punctured positions, thus resulting in the disadvantage that the distance between certain punctured positions is less than this corresponding integer and, in some cases, the punctured positions are even located alongside one another.

In order to describe the complex invention, the narrower technical field of the invention and the problems that occur in this case will be briefly explained in the following text with reference to Figures 1 to 6 and 9 but, at least partially, also result from the state of standardization for the 3rd mobile radio generation (UMTS (Universal Mobile Telecommunications System)) prior to the invention, which is specified in particular in the following document: S1.12 v0.0.1, 3GPP FDD, Multiplexing, channel coding and interleaving description.

The interleaving within a transport multiplexing method is frequently carried out in two steps. The various

solutions for carrying out the puncturing/repetition have various consequences if the puncturing is carried out after the first interleaver, as is envisaged from the UMTS

system. A second interleaver is now also used in the UMTS system, and is arranged after the physical channel segmentation and before the physical channel mapping (see Figure 1). Although this interleaver results in an improvement in the transmitted bits being distributed as uniformly as possible, it has no influence, however, on the distribution of the punctured/repeated bits, and will therefore not be discussed any further for the purposes of this invention.

Figure 1 shows the use of an FS-MIL (FS-Multistage Interleaver) as an interleaver in the uplink path multiplexing method, in conjunction with a known rate matching algorithm proposed for UMTS.

As an example, let us consider a situation in which layer 2 results in a transport block with 160 bits on a transport channel with a transmission interval of 80 ms. This bit sequence can also be described as a data frame, or as a sequence of data frames. This means that, after the first interleaver, (first interleaving), the data is interleaved over eight radio frames (often also referred to as "frames" or "columns" in the following text) (see Figure 2). In this case, the interleaving comprises the bits being read line-by-line, and the bits being read column-by-column with subsequent column randomizing (columns being interchanged).

A first aim of a good puncturing algorithm is to distribute punctured bits as uniformly as possible over the bit positions in their original sequence. This was also the critical principle which was used for the definition of the puncturing algorithm for UMTS, as is described, for example, in the abovementioned Specification S1.12. This is best done by puncturing

every n-th bit or, in some cases, every (n+first) bit if the puncturing rates are not integral.

A second aim is to puncture the various frames (in the following text, frames are also often referred to as columns or radio frames) with equal frequency, and hence also to distribute the punctured bits uniformly over all the frames, and also to achieve uniform puncturing in the various frames. The expressions puncturing or repetition of a column (for the frame) also mean the puncturing or repetition of an element, in particular of a bit in the column (the frame).

Let us now assume that four bits are intended to be punctured in each frame (radio frame) in order to produce a balance for the requirements for the quality of the service of this transport channel together with other channels. The result of the rate matching algorithm - previously intended for the UMTS system - is to puncture the bits 4, 9, 14 and 19 (index starts at 0, counting based on the sequence of the bits after the first interleaving) in each frame (radio frame). In Figure 2, a punctured bit is illustrated in bold text. In consequence, eight adjacent bits are punctured, and this, as explained above, is undesirable. The first aim mentioned above is not achieved to a satisfactory extent.

One procedure to avoid this problem would be to shift the puncturing pattern in each frame. Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_1 is the index of the punctured/repeated bit, k is the frame number and K is the number of interleaved frames.

Let us then consider the situation where $N_i > N_c$, that is to say puncturing. In the above example, $N_i=20$, $N_c=16$, $m_1=4$, $m_2=9$, $m_3=14$, $m_4=19$, $k=1...7$ and $K=8$. A shift in the positions of the bits to be punctured in order to avoid

the abovementioned problem can then be described by the following formula:

$m_{j\,shift} = (m_j + k*\lceil N_c/(N_c-N_c)/K\rceil) \bmod N_i$, where $\lceil\ \rceil$ means round up.

The positions of the bits to be punctured resulting from this formula are illustrated, for the above example, in Figure 3.

As can be seen from Figure 3, the puncturing of adjacent bits is admittedly avoided to a certain extent, but this results in a cyclic effect or edge effect, that is to say for example, bits 43 and 44 are punctured, which, as explained above - is undesirable. The first aim mentioned above is accordingly once again not achieved to a satisfactory extent.

If the puncturing ratio is low, the probability of puncturing adjacent bits decreases. Figure 4 shows an example with 10% puncturing. As can be seen from Figure 4, some adjacent bits (bit 91 and bit 92) are still punctured, however, which results in a reduction in performance. Once again, the first aim mentioned above is not achieved to a satisfactory extent.

As an alternative to a described rate matching algorithm, it is proposed that the first interleaver (first interleaving) be optimized such that the puncturing no longer requires the described rate matching algorithm. An optimized first interleaver should reorder the bits such that adjacent bits are separated. The puncturing can accordingly be carried out simply by removing successive bits after the interleaving process. However, the following two options, which will be explained in more detail with reference to the scenario illustrated in Figure 5.

The four blocks on TrCH A are interleaved together, and the rate matching is then carried out. When puncturing is carried out, successive bits are removed in each

frame. It is therefore highly improbable that punctured bits would be adjacent in a frame, with respect to their position before the interleaving process, that is to say after coding. However, there is no guarantee that punctured bits would not be adjacent in different frames after the coding process. In consequence, a reduction in performance could occur when using this approach.

The method explained in the following text with reference to Figure 6 could be used to solve the problem explained with reference to Figure 4, in which method the puncturing pattern applied to a frame is also applied, after shifting, to other frames, with the shifted patterns being applied to frames before the interleaving process. Figure 6 shows a puncturing pattern for the bit sequence example which has already been explained with reference to Figure 3. The illustration shows that no puncturing of adjacent bits occurs, at least in this example. The reduction in performance resulting from puncturing should therefore be avoided in this case.

In fact, there is no need to carry out the above rate matching before the column randomization (column interchanging). Rate matching equivalent to this can be carried out after the column randomization by taking account of the column randomization rules, and this can easily be achieved just by replacing the initial column-specific offset value e_{offset}, which describes this shift in the application of the puncturing pattern by a simple formula. The offset value is not calculated on the basis of the column number after column randomization, but the column number before the column randomization, and this can be calculated using the inverse column interchanging rule. Furthermore, e_{offset} can be used not used just for puncturing, but also for

repetition. Repetition bits can thus also be positioned more uniformly.

The following text once again shows, in summary form, that the previously proposed solutions, that is to say the proposed puncturing/repetition patterns, are still not always optimum in all cases.

In the introduction, it was shown with reference to Figure 2 and by analysis by way of example of a situation in which layer 2 provides a transport block with 160 bits on a transport channel with a transmission interval of 80 ms, and subject to the precondition that four bits should be punctured in each frame, that eight adjacent bits are punctured, which is obviously undesirable. The first aim mentioned above is not achieved to a satisfactory extent.

The proposal as shown in Figures 3 and 4 was to shift the puncturing pattern in each frame. Once again, as shown, this led to puncturing of adjacent bits (bits 43 and 44 as well as bits 91 and 92). The first aim mentioned above is not achieved to a satisfactory extent.

The proposal as shown in Figure 6 provides for the use of shifted puncturing patterns after the interleaving process, in which case the column-specific shifts were determined on the basis of analyses before column interchanging. In this case, this does not lead to any adjacent punctured bits in this example.

However, in a method as shown in Figure 6, there are always still situations in which adjacent bits are punctured, depending on the puncturing rate. Figure 9 shows, by way of example, the situation N_i=16, N_c=14, m_1=4, m_2=14, k=1...7 and K=8. For the sake of simplicity, Figures 9 and 10 show only the area before interleaving, in which, however, those bit positions which are punctured after interleaving are illustrated

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by marking them in bold print. As can be seen, the adjacent bits 31 and 32 and 95-96 are punctured, which is obviously undesirable. Once again, the first aim mentioned above is not achieved to a satisfactory extent.

If, in contrast, only every n-th bit were to be punctured with respect to the original sequence after the interleaver process, then the second aim cannot always be achieved adequately. Let us assume, for example, 80-ms interleaving (as in Figure 9) and a puncturing rate of 1:6. Puncturing every sixth bit would result in only the columns 0, 2, 4, 6 being punctured, but not the columns 1, 3, 5, 7, which is, of course undesirable and is not consistent with the second aim. In contrast, the first aim would be achieved to a satisfactory extent.

Against this background, the invention is based on the object of reducing these disadvantages of the prior art.

This object is achieved by the features of the independent claims. Developments of the invention can be found in the dependent claims.

Embodiments of the present invention will now be described just by way of example with reference to the attached drawings, in which:

Figure 1 shows a simplified flowchart with an interleaver before rate matching (prior art);

Figure 2 shows interleaving and puncturing patterns for puncturing of four bits per frame (prior art);

Figure 3 shows interleaving and shifted puncturing patterns for puncturing of four bits per frame (prior art);

Figure 4 shows interleaving and shifted puncturing patterns for puncturing with a puncturing ratio of 10% (prior art);

Figure 5 shows a simplified illustration of transport channels (prior art);

Figure 6 shows interleaving and shifted puncturing patterns for puncturing of four bits per frame (prior art);

Figure 7 shows a block diagram of a mobile radio communications system (prior art);

Figure 8 shows a block diagram of a data communications arrangement, which forms a path between the mobile station and a base station in the communications network shown in Figure 7 (prior art);

Figure 9 shows puncturing patterns for shifted puncturing patterns for puncturing of two bits per frame (prior art);

Figure 10 shows a simplified illustration of the principle of puncturing which is optimized with regard to the two said aims;

Figure 11 shows a reference table;

Figure 12 shows puncturing patterns for puncturing with a puncturing ratio of 20%;

Figure 13 shows puncturing patterns for puncturing with a puncturing ratio of 1:8;

Figure 14 shows puncturing patterns for puncturing with an odd number of bits to be punctured per frame.

As explained above, the second aim can admittedly not always be achieved adequately if every n-th bit were simply to be punctured after interleaving with respect to the original sequence before interleaving. However, the first aim would be achieved to an adequate extent.

In order to achieve both the abovementioned aims to a satisfactory extent, one embodiment variant of the invention now provides - in contrast to the uniform puncturing with respect to the original sequence before interleaving - that the puncturing interval be varied at least once, and if necessary a number of times, in order to avoid some columns being preferred for puncturing, while others, on the other hand, are not punctured at all. This is shown in Figure 10. Horizontal arrows (P6) with thin surrounding lines show a puncturing distance of 6, and the horizontal arrow (P5) with thick surrounding lines shows a puncturing distance of 5, in order to avoid puncturing the first column twice. Once each column has been punctured once, the pattern (as shown by the vertical arrows) can be shifted six lines downward, in order to define the next bits to be punctured. This obviously corresponds to puncturing of every sixth bit in each column, that is to say it corresponds to the use of a standard rate matching algorithm, and to the shifting of puncturing patterns with respect to one another in different columns.

This method will now be described using formulae in the following text:

Let us assume that N_i is the number of bits in a frame before rate matching, N_c is the number of bits after rate matching, m_j is the index of the punctured/repeated bits, k the column or frame number after interleaving and K the number of interleaved columns or frames. The

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aim is to consider mainly the situation $N_i > N_c$, that is to say puncturing, but the formulae are also applicable to repetition.

In the above example, $N_i=20$, $N_c=16$, $m_1=4$, $m_2=9$, $m_3=14$, $m_4=19$, $k=1...7$, with k denoting the column or frame number after interleaving, and $K=8$. A comment is indicated by a prefix "--". The shifts $V(k) = S(k) + T(k) * Q$ in the application of the puncturing or repetition pattern to the frame k can then be determined using the following method:

-- Calculation of the mean puncturing distance

$q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$ -- where $\lfloor\ \rfloor$ means round down and $|\ |$ means absolute value.

$Q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \operatorname{div} K$

if q even -- deal with as a special case:

then $q = q - \operatorname{lcd}(q, K)/K$ -- where lcd(q, K) means the highest common denominator of q and K

-- It should be remembered that lcd can easily be calculated by bit manipulation, since K is a power of 2.

-- For the same reason, calculations with q can easily be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S and T; S represents the shift in the line mod K, and T represents the shift magnitude div K;

S thus represents the shift in the line with respect to q (that is to say mod K) and T the magnitude of the shift with respect to Q (that is to say div K);

for i = 0 to K-1

$S(R_K(\lceil i*q\rceil \bmod K)) = (\lceil i*q\rceil \operatorname{div} K)$ - where $\lceil\ \rceil$ means round up.

$T((R_K(\lceil i*q\rceil \bmod K)) = i$ -- $R_K(k)$ reverses the interleaver,

end for

In an actual implementation, these formulae can be implemented as shown in Figure 11, as a reference

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table. The table also includes the already described effect of the remapping of the column randomization

achieved by $R_K(k)$. S can obviously also be calculated from T, as a further implementation option.

e_{offset} can then be calculated as follows:

$e_{offset}(k) = ((2*S) + 2*T\ Q + 1) * y + 1) \bmod 2Nc$

Using $e_{offset}(k)$, e is then preloaded in the rate matching method for UMTS. This choice of e_{offset} obviously results in a shift in the puncturing patterns in the columns relative to one another by the amount S + T * Q.

The following text describes a simplified representation which simply results from the calculation of q and Q not being carried out separately for the remainder in the division by K and the multiple of K, but being combined for both components. In the same way, S and T cannot be calculated separately for q and Q, but likewise combined. The substitutions q+K*Q --> q and S+Q*T --> S result in the following equivalent representation of the method specified above, with the shift at V(k) in this case being given by: V(k) = S(k). Depending on the details of the implementation, it may be better to carry out one calculation method or the other calculation method or (further methods which are likewise equivalent to them).

-- Calculation of the mean puncturing distance

$q := (\lfloor N_c/(|N_i - N_c|)\rfloor)$ -- where $\lfloor\ \rfloor$ means round down and $|\ |$ means absolute value.

if q even -- deal with as a special case:

then q = q - lcd(q, K)/K -- where lcd(q, K) means the highest common denominator of q and K

-- It should be noted that lcd can easily be calculated by bit manipulation, since K is a power of 2.

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-- For the same reason, calculations with q can easily be carried out using binary fixed-point arithmetic (or integer arithmetic and a small number of shift operations).

endif

-- Calculation of S(k) for the shift in the column k;

for i = 0 to K-1

$S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$ -- where $\lceil\ \rceil$ means round up.

-- $R_K(k)$ reverses the interleaver

end for

e_{offset} can then be calculated as follows:

$e_{offset}(k) = ((2*S) * y + 1) \bmod 2Nc$

Using $e_{offset}(k)$, e is then initialized in advance in the rate matching method.

If the puncturing rate is an odd-numbered fraction, that is to say 1:5 or 1:9, this method likewise produces a puncturing pattern which is optimum with regard to the two aims mentioned above and which would be used directly before the interleaving by the puncturing using the rate matching method. In other situations, adjacent bits are never punctured, but the distance between adjacent punctured bits may be greater than the others by up to lcd(q,K)+1. This method can also be applied in a corresponding manner to bit repetitions. Although the repetition of adjacent bits does not have such a severe influence on the performance of the error correction codes as is the case when puncturing adjacent bits, it is nevertheless advantageous to distribute repeated bits as uniformly as possible.

The fundamental objective of this method is to achieve a uniform distance between the punctured bits in the original sequence, but taking account of the constraint that the same number of bits must be punctured in the various frames. This is achieved be reducing the puncturing distance by 1 in certain cases. The described method is optimum to the extent that the distance is never reduced by more than 1, and it is reduced only as often as is

necessary. This results in the best-possible puncturing pattern subject to the constraints mentioned above.

The following example uses Figure 12 to show puncturing with a puncturing ratio of 1:5. The optimized algorithm obviously not only avoids the puncturing of adjacent bits, but punctured bits are also distributed with the same spacing in the original sequence. In fact, the same characteristics are achieved as if the puncturing were to be carried out directly after the coding and before the interleaving. In the specific case of 1:5 puncturing and, to put this in more general terms, whenever the puncturing rate can be written as a fraction 1:q, where q is an integer and q and K, the number of frames, do not have a common denominator, it can be said that an optimum puncturing pattern is produced despite the use of puncturing after the first interleaver. This puncturing pattern results in the puncturing of every qth bit, in the same way as an optimum puncturing pattern which had been carried out immediately after the coding and before the interleaving.

Puncturing with a puncturing ratio of 1:8 will now be analyzed with reference to Figure 13. Once again, the puncturing of adjacent bits is avoided. In this case, it is impossible to achieve uniformly spaced puncturing, since all the bits in an individual frame would then be punctured, which is completely unacceptable with respect to the second aim. In this case, most of the distances between adjacent bits are 7 (only one less than with an optimum distribution). In this case, some distances are greater (every eighth).

If the number N_i of input bits can be divided by K, the rate matching may vary during the transmission time interval. The last frames then have one bit less than

the first, and therefore also have a somewhat lower puncturing rate. For this situation, one embodiment

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variant of the invention provides for the puncturing patterns in the last lines not to be changed. Instead of this, the same puncturing algorithm is used as for the first columns, but without carrying out the last puncturing operation. It can be seen from Figure 14 as an example that 125 input bits are intended to be punctured in such a manner that 104 output bits remain, which are interleaved over eight frames. The last two columns have one input bit less than the first; all the columns have 13 bits, since the last puncturing operation in the last two columns is omitted.

With regard to the aims mentioned above, the method proposed here allows optimized puncturing patterns to be specified when the rate matching is carried out after the first interleaving. The method is simple, requires little computation power and need be carried out only once per frame, and not once per bit. The method is not restricted to radio transmission systems.

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Patent Claims

1. A method for data rate matching in which data to be transmitted is distributed in the form of bits by means of a first interleaver to a set of K frames, in which a puncturing or repetition method is carried out for data rate matching after the interleaving, in that for puncturing or repeating the same number of bits in each frame, the distance between punctured or repeated bits is varied with regard to the sequence of the bits before the first interleaver, with the separation being defined by the following relationship:
$q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1$, where:
$q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ means round down and $|\ |$ means absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching;
$\text{lcd}(q, K)$:= highest common denominator of q and K.

2. The method as claimed in claim 1, in which the following relationship is also valid when the puncturing rate or the repetition rate is equal to 1/K:
$q-1 \leq \text{distance} \leq q + \text{lcd}(q,K) + 1$, where:
$q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ means round down and $|\ |$ means absolute value, and where N_i := the number of bits after rate matching, N_c := the number of bits before rate matching;
$\text{lcd}(q, K)$:= highest common denominator of q and K.

3. The method as claimed in one of claims 1 or 2,

in which punctured or repeated bits which are adjacent with regard to the sequence of bits before the first interleaver are obtained by a method which includes the following steps:

a) puncturing or repetition with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q;

b) variation of the distance to q-1 or q+1 between adjacent punctured or repeated bits, if the number of punctured or repeated bits in a frame would exceed the number of punctured or repeated bits in another frame by more than one and if, furthermore, the puncturing or repetition were carried out with a distance with regard to the sequence of the bits before the first interleaver between adjacent punctured or repeated bits of magnitude q;

c) continuation with step a), if any further bits need to be punctured or repeated.

4. The method as claimed in one of claims 1, 2 or 3, in which a puncturing or repetition process is carried out in such a manner that the puncturing or repetition pattern used within a frame is also used, shifted, within further frames in the set of frames.

5. The method as claimed in claim 4, in which the shift V(k) = S(k) + T(k) * Q in the use of the puncturing or repetition pattern to the frame k can be produced by means of the following steps:

- Calculation of the mean puncturing distance q=, in which case: $q := (\lfloor N_c/(|N_i-N_c|)\rfloor) \bmod K$, where $\lfloor\ \rfloor$ means round down and $|\ |$ means absolute value, and in which case:

N_i := the number of bits after rate matching,

N_c := the number of bits before rate matching;

- Calculation of Q, in which case: $Q := ((\lfloor N_c/(|N_i-N_c|)\rfloor)$ div K;

- if q is even, then q is set to q - lcd(q, K)/K where lcd(q, K):= the highest common denominator of q and K; - a variable i is set to zero;

- Repetition of the following steps as long as $i \leq K-1$:
  - $S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$, where $\lceil\ \rceil$ means round up;
  - $T((R_K(\lceil i*q \rceil \bmod K)) = i$, where $R_K(k)$ reverses the interleaver;
  - i becomes $i + 1$.

6. The method as claimed in claim 4, in which the shift $V(k) = S(k)$ of the use of the puncturing and repetition pattern to the frame k can be produced by means of the following steps:
-- Calculation of the mean puncturing distance q, in which case:
$q := (\lfloor N_c / (|N_i - N_c|) \rfloor)$, where $\lfloor\ \rfloor$ means round down and $|\ |$ means absolute value,
and in which case:
N_i := the number of bits after rate matching,
N_c := the number of bits before rate matching;
- if q is even, then q is set to $q - \mathrm{lcd}(q, K)/K$, where $\mathrm{lcd}(q, K)$:= the highest common denominator of q and K; - a variable i is set to zero;
- Repetition of the following steps as long as $i \leq K-1$:
  - $S(R_K(\lceil i*q \rceil \bmod K)) = (\lceil i*q \rceil \operatorname{div} K)$, where $\lceil\ \rceil$ means round up;
  - $R_K(k)$, where $R_K(k)$ reverses the interleaver;
  - i becomes $i + 1$.

7. The method as claimed in one of the preceding claims, in which bits which are to be punctured or to be repeated are produced by means of a method which includes the following steps:
a) Determine the integer component q of the mean puncturing distance using
$q := (\lfloor N_c / (|N_i - N_c|) \rfloor)$,

where $\lfloor\ \rfloor$ means round down and $|\ |$ means absolute value,

and in which case:

N_i := the number of bits after rate matching,

N_c := the number of bits before rate matching;

b) Select a bit to be punctured or to be repeated in a first column;

c) Select the next bit to be punctured or to be repeated in the next frame, starting from the last bit to be punctured or to be repeated in the previous frame by in each case selecting the next bit at the distance q, with respect to the original sequence, starting with this last bit to be punctured or to be repeated, providing this does not lead to a frame being punctured or repeated twice, or else by selecting a bit with a distance which has been changed from q to q-1 or q+1 for puncturing or repetition;

d) repetition of step c) until all columns have been punctured or repeated once.

8. The method as claimed in claim 7, in which bits in a first frame are punctured or repeated in accordance with a predetermined puncturing pattern or repetition pattern, and in order to select further bits to be punctured or to be repeated, the puncturing pattern or repetition pattern is applied, shifted, to further frames, with the shift in the application of the puncturing pattern or repetition pattern to a further frame corresponding to the shift of the bit, chosen in step c) of claim 7, in the further frame with respect to the bit chosen in step b) of claim 7.

9. A data rate matching apparatus, in particular a processor device, having means for carrying out a method as claimed in one of claims 1 to 8.

PCT

ORGANISATION FÜR GEISTIGES EIGENTUM
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INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)

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(81) Bestimmungsstaaten: CN, HU, IN, JP, KR, US, europäisches Patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Veröffentlicht
Mit internationalem Recherchenbericht.
Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist; Veröffentlichung wird wiederholt falls Änderungen eintreffen.

(54) Title: DATA TRANSMISSION WITH INTERLEAVING AND SUBSEQUENT RATE MATCHING BY PUNCTURING OR REPETITION

(54) Bezeichnung: DATENÜBERTRAGUNG MIT VERSCHACHTELUNG UND ANSCHLIESSENDER RATENANPASSUNG DURCH PUNKTIERUNG ODER WIEDERHOLUNG

(57) Abstract

According to the invention, the elements to be transmitted are distributed and punctured or repeated by an interleaver, wherein puncturing or repetition is carried out in such a way that the pattern, when it is related to the original arrangement of the elements before interleaving, prevents puncturing or repetition of adjacent elements or elements located not far from one another.

(57) Zusammenfassung

Zu übertragende Elemente werden durch einen Verschachtler auf mehrere Funkrahmen verteilt und punktiert oder wiederholt, wobei die Punktierung oder Wiederholung derart durchgeführt wird, daß das Muster, wenn es mit der ursprünglichen Anordnung der Elemente vor dem Verschachteln in Beziehung gesetzt wird, ein Punktieren bzw. Wiederholen benachbarter Elemente oder nicht weit auseinanderliegender Elemente vermeidet.

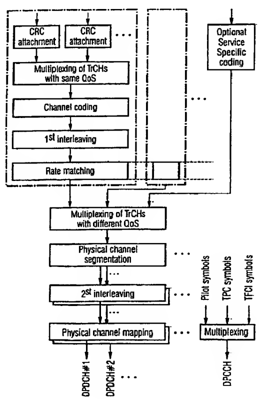
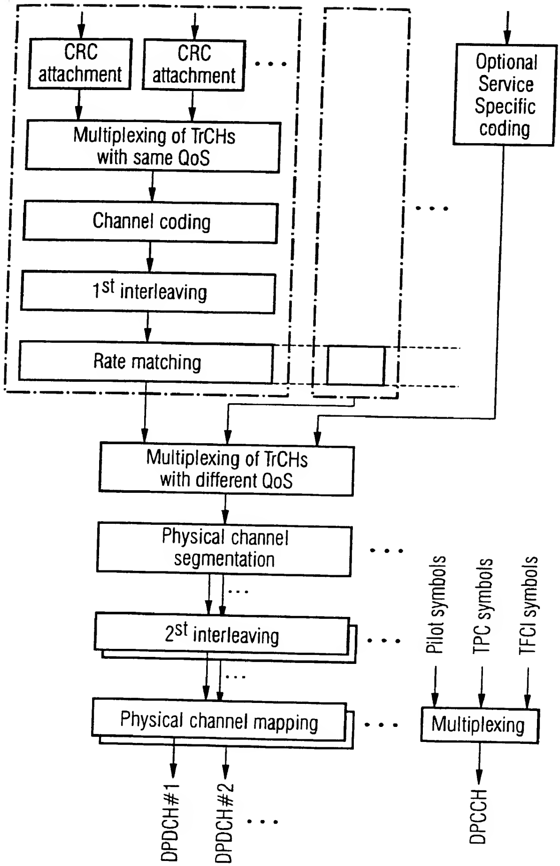


FIG 1


CRC attachment
CRC attachment
Optional Service Specific coding
Multiplexing of TrCHs with same QoS
Channel coding
1st interleaving
Rate matching
Multiplexing of TrCHs with different QoS
Physical channel segmentation
2st interleaving
Physical channel mapping
Pilot symbols
TPC symbols
TFCI symbols
Multiplexing
DPDCH#1
DPDCH#2
DPCCH

2/12

FIG 2

Bit sequence: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...159

Row by row processing
8[4[2x2]x2]

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151
152	153	154	155	156	157	158	159

1st interleaving

0	4	2	6	1	5	3	7
8	12	10	14	9	13	11	15
16	20	18	22	17	21	19	23
24	28	26	30	25	29	27	31
32	**36**	**34**	**38**	**33**	**37**	**35**	**39**
40	44	42	46	41	45	43	47
48	52	50	54	49	53	51	55
56	60	58	62	57	61	59	63
64	68	66	70	65	69	67	71
72	**76**	**74**	**78**	**73**	**77**	**75**	**79**
80	84	82	86	81	85	83	87
88	92	90	94	89	93	91	95
96	100	98	102	97	101	99	103
104	108	106	110	105	109	107	111
112	**116**	**114**	**118**	**113**	**117**	**115**	**119**
120	124	122	126	121	125	123	127
128	132	130	134	129	133	131	135
136	140	138	142	137	141	139	143
144	148	146	150	145	149	147	151
152	**156**	**154**	**158**	**153**	**157**	**155**	**159**

Radio frame #1

Radio frame #2

...

Radio frame #8

FIG 3

Bit sequence 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...159

Row by row processing
8[4[2x2]x2]

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151
152	153	154	155	156	157	158	159

0	**4**	2	6	1	5	**3**	7
8	12	**10**	14	9	13	11	**15**
16	20	18	**22**	17	21	19	23
24	28	26	30	**25**	29	27	31
32	36	34	38	33	**37**	35	39
40	**44**	42	46	41	45	**43**	47
48	52	**50**	54	49	53	51	**55**
56	60	58	**62**	57	61	59	63
64	68	66	70	**65**	69	67	71
72	76	74	78	73	**77**	75	79
80	**84**	82	86	81	85	**83**	87
88	92	**90**	94	89	93	91	**55**
96	100	98	**102**	97	101	99	103
104	108	106	110	**105**	109	107	111
112	116	114	118	113	**117**	115	119
120	**124**	122	126	121	125	**123**	127
128	132	**130**	134	129	133	131	**135**
136	140	138	**142**	137	141	139	143
144	148	146	150	**145**	149	147	151
152	156	154	158	153	**157**	155	159

Radio frame #1

Radio frame #2

...

Radio frame #8

Bit sequence 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...159

FIG 4

Row by row processing
8[4[2x2]x2]

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151
152	153	154	155	156	157	158	159

0	4	2	6	1	5	3	7
8	**12**	10	14	9	13	**11**	15
16	20	18	22	17	21	19	23
24	28	**26**	30	25	29	27	**31**
32	36	34	38	33	37	35	39
40	44	42	**46**	41	45	43	47
48	52	50	54	49	53	51	55
56	60	58	62	**57**	61	59	63
64	68	66	70	65	69	67	71
72	76	74	78	73	**77**	75	79
80	84	82	86	81	85	83	87
88	**92**	90	94	89	93	**91**	55
96	100	98	102	97	101	99	103
104	108	**106**	110	105	109	107	**111**
112	116	114	118	113	117	115	119
120	124	122	**126**	121	125	123	127
128	132	130	134	129	133	131	135
136	140	138	142	**137**	141	139	143
144	148	146	150	145	149	147	151
152	156	154	158	153	**157**	155	159

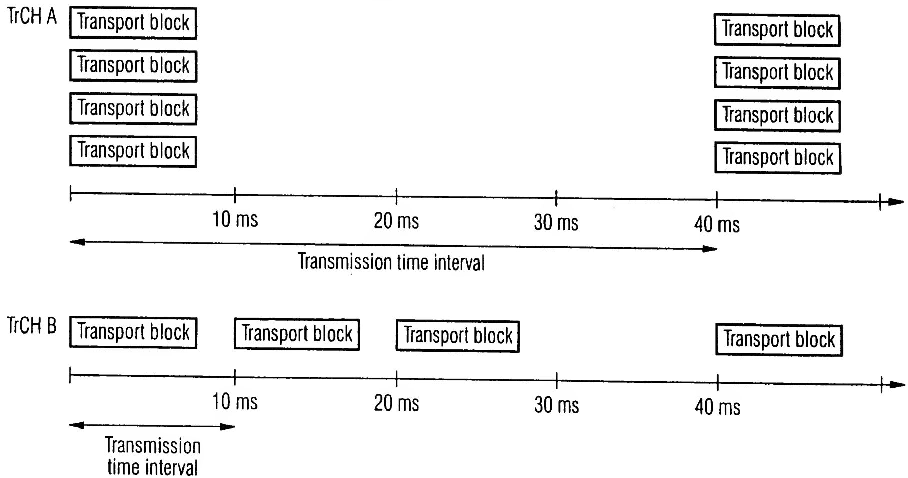
Radio frame #1

Radio frame #2

...

Radio frame #8

FIG 5


TrCH A
Transport block
Transport block
Transport block
Transport block
Transport block
Transport block
Transport block
Transport block
10 ms
20 ms
30 ms
40 ms
Transmission time interval
TrCH B
Transport block
Transport block
Transport block
Transport block
10 ms
20 ms
30 ms
40 ms
Transmission
time interval

Input bit sequence: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 ...159

1st stage block Interleaving

FIG 6

Puncturing with simple shifting rule

0	1	2	3	4	**5**	6	7
8	**9**	10	11	12	13	**14**	15
16	17	**18**	19	20	21	22	**23**
24	25	26	**27**	28	29	30	31
32	33	34	35	**36**	37	38	39
40	41	42	43	44	**45**	46	47
48	**49**	50	51	52	53	**54**	55
56	57	**58**	59	60	61	62	**63**
64	65	66	**67**	68	69	70	71
72	73	74	75	**76**	77	78	79
80	81	82	83	84	**85**	86	87
88	**89**	90	91	92	93	**94**	95
96	97	**98**	99	100	101	102	**103**
104	105	106	**107**	108	109	110	111
112	113	114	115	**116**	117	118	119
120	121	122	123	124	**125**	126	127
128	**129**	130	131	132	133	**134**	135
136	137	**138**	139	140	141	142	**143**
144	145	146	**147**	148	149	150	151
152	153	154	155	**156**	157	158	159

Column randomizing

0	4	2	6	1	**5**	3	7
8	12	10	**14**	**9**	13	11	15
16	20	**18**	22	17	21	19	**23**
24	28	26	30	25	29	**27**	31
32	**36**	34	38	33	37	35	39
40	44	42	46	41	**45**	43	47
48	52	50	**54**	**49**	53	51	55
56	60	**58**	62	57	61	59	**63**
64	68	66	70	65	69	**67**	71
72	**76**	74	78	73	77	75	79
80	84	82	86	81	**85**	83	87
88	92	90	**94**	**89**	93	91	55
96	100	**98**	102	97	101	99	**103**
104	108	106	110	105	109	**107**	111
112	**116**	114	118	113	117	115	119
120	124	122	126	121	**125**	123	127
128	132	130	**134**	**129**	133	131	135
136	140	**138**	142	137	141	139	**143**
144	148	146	150	145	149	**147**	151
152	**156**	154	158	153	157	155	159

Frame #1 Frame #2 ... Frame #8

FIG 7

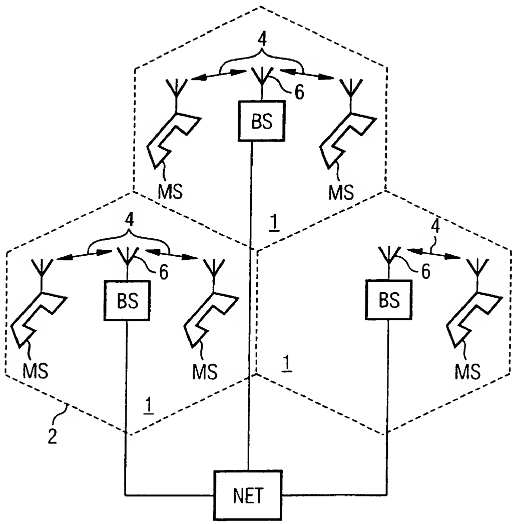


FIG 8

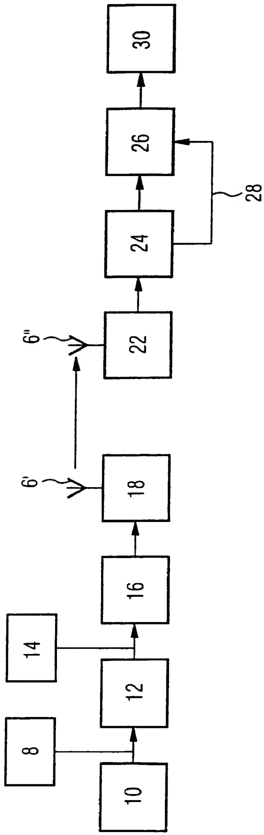


FIG 9

0	1	2	3	**4**	5	6	7
8	9	10	11	12	**13**	14	15
16	17	18	19	20	21	**22**	23
24	25	26	27	28	29	30	**31**
32	33	34	35	36	37	38	39
40	**41**	42	43	44	45	46	47
48	49	**50**	51	52	53	54	55
56	57	58	**59**	60	61	62	63
64	65	66	67	**68**	69	70	71
72	73	74	75	76	**77**	78	79
80	81	82	83	84	85	**86**	87
88	89	90	91	92	93	94	**95**
96	97	98	99	100	101	102	103
104	**105**	106	107	108	109	110	111
112	113	**114**	115	116	117	118	119
120	121	122	**123**	124	125	126	127

P6 P5

FIG 10

0	1	2	3	4	5	**6**	7
8	9	10	11	**12**	13	14	15
16	17	**18**	19	20	21	22	**23**
24	25	26	27	28	**29**	30	31
32	33	34	**35**	36	37	38	39
40	**41**	42	43	44	45	46	47
48	49	50	51	52	53	**54**	55
56	57	58	59	**60**	61	62	63
64	65	**66**	67	68	69	70	**71**
72	73	74	75	76	**77**	78	79
80	81	82	**83**	84	85	86	87

FIG 11

S;T	K	1	2		4				8							
	k	0	0	1	0	1	2	3	0	1	2	3	4	5	6	7
Q	1	0;0	0;0	0;1	0;0	0;2	0;1	0;3	0;0	0;4	0;2	0;6	0;1	0;5	0;3	0;7
	2		0;0	1;1	0;0	0;1	1;3	0;2	0;0	0;2	0;1	0;3	1;5	1;7	1;6	0;4
	3				0;0	1;2	2;3	0;1	0;0	1;4	2;6	0;2	1;3	2;7	0;1	1;5
	4				0;0	1;2	2;3	0;1	0;0	0;1	2;5	1;4	3;7	2;6	1;3	0;2
	5								0;0	3;4	2;2	4;6	4;5	1;1	5;7	2;3
	6								0;0	1;2	2;3	0;1	5;7	3;5	4;6	2;4
	7								0;0	3;4	5;6	1;2	6;7	2;3	4;5	0;1
	8								0;0	3;4	5;6	1;2	6;7	2;3	4;5	0;1

FIG 12

0	1	**2**	3	4	5	6	**7**
8	9	10	11	**12**	13	14	15
16	**17**	18	19	20	21	**22**	23
24	25	26	**27**	28	29	30	31
32	33	34	35	36	**37**	38	39
40	41	**42**	43	44	45	46	**47**
48	49	50	51	**52**	53	54	55
56	**57**	58	59	60	61	**62**	63
64	65	66	**67**	68	69	70	71
72	73	74	75	76	**77**	78	79
80	81	**82**	83	84	85	86	**87**
88	89	90	91	**92**	93	94	95
96	**97**	98	99	100	101	**102**	103
104	105	106	**107**	108	109	110	111
112	113	114	115	116	**117**	118	119
120	121	**122**	123	124	125	126	**127**
128	129	130	131	**132**	133	134	135
136	**137**	138	139	140	141	**142**	143
144	145	146	**147**	148	149	150	151
152	153	154	155	156	**157**	158	159

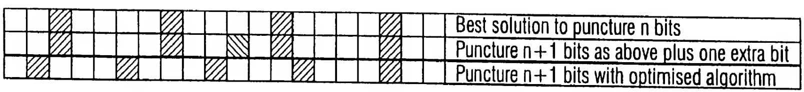
FIG 13

0	1	2	**3**	4	5	6	7
8	9	**10**	11	12	13	14	15
16	**17**	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	**39**
40	41	42	43	44	45	**46**	47
48	49	50	51	52	**53**	54	55
56	57	58	59	**60**	61	62	63
64	65	66	**67**	68	69	70	71
72	73	**74**	75	76	77	78	79
80	**81**	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	**103**
104	105	106	107	108	109	**110**	111
112	113	114	115	116	**117**	118	119
120	121	122	123	**124**	125	126	127

FIG 14

0	1	2	**3**	4	5	6	7
8	9	**10**	11	12	13	14	15
16	**17**	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	**39**
40	41	42	43	44	45	**46**	47
48	49	50	51	52	**53**	54	55
56	57	58	59	**60**	61	62	63
64	65	66	**67**	68	69	70	71
72	73	**74**	75	76	77	78	79
80	**81**	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	**117**	118	119
120	121	122	123	**124**	125		

FIG 15



Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Datenübertragung mit Verschachtelung und anschließender Ratenanpassung durch Punktierung oder Wiederholung

Data transmission with interleaving and subsequent rate matching by puncturing or repetition

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 20.03.2000 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/EP00/02440
eingereicht wurde und am ______
abgeändert wurde (falls tatsächlich abgeändert).

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 20.03.2000 as
PCT international application
PCT Application No. PCT/EP00/02440
and was amended on ______
(if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

IDNR: 2590 / V: 99-1.00 / B:Val

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Prior foreign appplications
Priorität beansprucht

Priority Claimed

99105680.5 (Number) (Nummer)	EP (Country) (Land)	19.03.1999 (Day Month Year Filed) (Tag Monat Jahr eingereicht)	☒ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/EP00/02440 (Application Serial No.) (Anmeldeseriennummer)	20.03.2000 (Filing Date D, M, Y) (Anmeldedatum T, M, J)	anhängig (Status) (patentiert, anhängig, aufgegeben)	pending (Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschäfte vor dem Patent- und Warenzeichenamt: *(Name und Registrationsnummer anführen)*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

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1-W

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